Kanalku, Kook, And Sitkoh Subsistence Sockeye Salmon Project, 2002 Annual Report

by

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ACKNOWLEDGEMENTS

Foremost acknowledgement goes to our cooperator, the Angoon Community Association. Under the leadership of Walter Jack, President, and Marlene Zuboff, Executive Director, the second year of project work was accomplished efficiently and with the highest level of cooperation. The ACA Council met with us formally in March 2002, and we maintained contact with members throughout the year. ADF&G Subsistence Biologist Matt Kookesh once again assisted us in our understanding of the community and issues important to it. Matt Kookesh, Angoon mayor Floyd Kookesh, ACA president Walter Jack, and ADF&G area management biologist Craig Farrington were instrumental in initiating a voluntary fishing closure in Kanalku Bay during the 2002 season. Ben Van Alen of the U.S. Forest Service fulfilled another vital link in the cooperative relationship, helping again with clearing the Kook Lake outlet and in establishing a local sockeye-monitoring program in Kanalku Bay during the initial stages of the run, in cooperation with ADF&G management.

Dave Harris of ADF&G provided excellent leadership in the 2002 field operations, and provided support and training to enable returning ACA crew members Leroy Martin and Peter McCluskey to take over the crew leader role. Leroy and Peter are the backbone of a solid, hard-working and knowledgeable team. We also appreciate the hard work and energy of ACA crewmembers Jason Frank and Ed Gamble. The crew made great progress during the 2002 season in improving the field camps, travel routines, and sampling procedures. Their flexibility and willingness to try new ways of doing things was outstanding.

The authors acknowledge the expert assistance of the following groups and individuals at ADF&G: John Edmondson and the Soldotna limnology lab crew for processing the zooplankton samples; Iris Frank, Mark Olsen and the commercial fisheries scale and age lab crew for analyzing scale, length, and age data; Xinxian Zhang for statistical advice and programming; and Malcolm McEwen for conducting the juvenile sampling fieldwork and data analysis. We thank Conan Steele of ADF&G in Ketchikan for assisting with the fry sampling, and Renate Riffe and Mike Parker of ADF&G for assisting with limnology sampling. We acknowledge the Angoon residents and subsistence fishers for maintaining strong subsistence traditions while demonstrating their willingness to cooperate with other agencies in developing sustainable management policies.

Finally, with great sadness we acknowledge the passing of former ACA crewmember Walter Jack Jr., in an accident in Mitchell Bay in 2002.

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ABSTRACT

Escapements of sockeye salmon into Kanalku, Kook, and Sitkoh Lakes were estimated through observer counts and mark-recapture studies, and the age, length, and sex composition of these populations were estimated using standard measurements and scale sampling and analysis. Sockeye salmon fry populations in each lake were estimated using hydroacoustic and trawl sampling. Light intensity, temperature, and dissolved oxygen were monitored in each lake, and zooplankton species distribution, abundance, and biomass were estimated, using standard limnological methods. Project objectives were met in all three lakes for adult estimates but not for fry, due to difficulties in estimating species apportionment. An escapement of about 1,600 sockeye salmon was estimated in Kanalku Lake, a dramatic increase from the very low escapement estimated in 2001. The increase is likely a direct result of the voluntary subsistence fishing moratorium initiated by the Angoon community in 2002. The estimated escapement of about 3,000 sockeye salmon in Kook Lake was also a dramatic increase over 2001, and may be attributed to removal of large woody debris from the outlet stream in 2001 and 2002. The escapement of around 12,000 sockeye salmon in Sitkoh Lake is similar to estimates over the past four to six years, and indicates this stock is probably healthy. Sockeye fry densities were as expected, very low in Kanalku Lake and in Kook Lake; fry density was substantially higher in Sitkoh Lake relative to the others, but still perhaps below the potential productivity of this lake. Sockeye fry populations appear not to be limited in these lakes by prey availability: total zooplankton biomass, as well as biomass and relative abundance of the preferred prey species *Daphnia longiremis*, was high in all three lakes, compared with other sockeye rearing lakes in Southeast Alaska. Interestingly, Sitkoh Lake, which had the highest sockeye fry density, also had the highest prey biomass, in terms of both total zooplankton and *Daphnia*. The sockeye salmon runs produced by Kanalku, Kook, and Sitkoh Lakes are important traditional subsistence resources for the people of Angoon, who desire to continue their traditions and be good stewards of these resources.

Juvenile and adult sockeye populations, and associated habitat variables, should continue to be monitored in these three systems, especially as sockeye populations are allowed to recover from low numbers in Kanalku and Kook Lakes. Continued monitoring will allow fisheries managers, biologists, and subsistence users to make sure they are allowing adequate escapements and maintaining potential productivity in these systems.

INTRODUCTION

Kanalku Lake (ADF&G stream no. 112-67-58/60), Kook Lake (ADF&G stream no. 112-12-026), and Sitkoh Lake (ADF&G stream no. 113-59-005) have been part of the traditional territories of the Angoon Tlingit for as long as they have lived in the area (Goldschmidt et al. 1998; Figure 1). These streams have supplied salmon to the people of Angoon and nearby villages as far back as the oldest traditions recount, and continue to be important subsistence systems (George and Bosworth 1988; Conitz and Cartwright, 2002a, b). In recent years, there have been concerns about declining sockeye salmon returns and harvest opportunities in these traditional subsistence areas (A. McGregor ADF&G, personal communication 2001; M. Kookesh ADF&G, personal communication 2002).

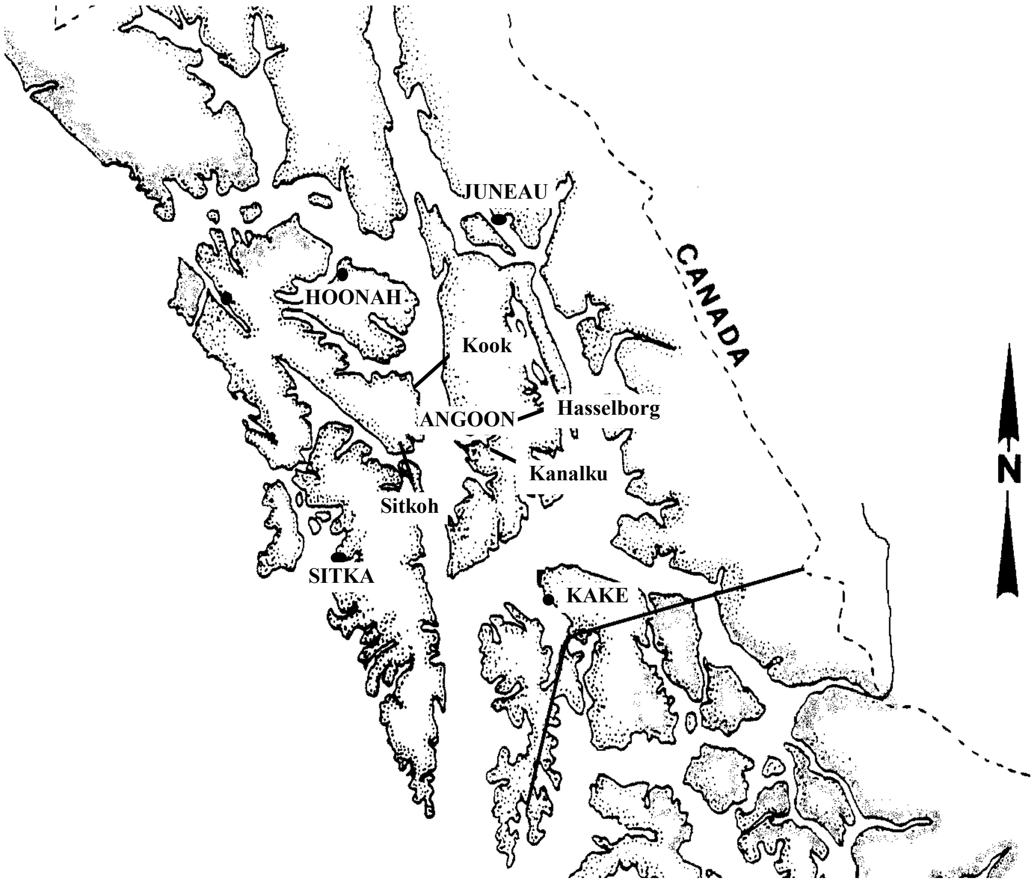

Figure 1. Map of Southeast Alaska showing location of Kanalku, Kook, and Sitkoh Lakes, and the village of Angoon.

Cultural and Subsistence Fishing History

Kanalku Bay and Kanalku Lake are part of the Kootznahoo Inlet and Mitchell Bay territory that were traditionally owned by the Deisheetan clan (Goldschmidt et al. 1998). Remains of a weir, and artifacts dated to at least 1,000 years ago have been found at the head of Kanalku Bay, showing a long continuity of subsistence activity and technology in this area (Moss 1989). From historic times to the present, this area is the one most frequently used by the people of Angoon for subsistence fishing and hunting (George and Bosworth 1988).

Basket Bay belonged to a group of the Angoon Deisheetan, known as the Kak'w.wedi, who had a tribal house there. People continued to live there until the early 1900s (de Laguna 1960; Goldschmidt et al. 1998). Angoon harvesters claimed that the Kook Lake sockeye salmon were larger than those from their other traditional sources, Sitkoh and Kanalku lakes. In addition to salmon fishing, Angoon residents have used the area for seal and deer hunting, and for gathering shellfish and other resources (George and Bosworth 1988). People from Hoonah, Tenakee, and Juneau also use Kook Lake for subsistence and personal use sockeye salmon fishing.

Sitkoh Bay and Lake were once owned by the Ganaxadi clan, but were turned over to the Deisheetan when the Ganaxadi left the Angoon area (de Laguna 1960). Some of the Sitka Deisheetan also had fishing rights at Sitkoh, after fleeing the Russians at Sitka. Commercial fishing began over the protest of these clans in 1890, and in 1900 the Chatham Cannery was built in Sitkoh Bay, under an agreement with the Deisheetan, which nominally allowed the clan to retain traditional ownership and control over the village and bay. The cannery closed in 1974 (Thornton et al. 1990).

In modern times, salmon is among the most important subsistence resources for residents of Angoon, with sockeye salmon being the preferred species (Table 1). A 1996 household survey found that four out of five Angoon households used subsistence salmon and two-thirds of Angoon households used sockeye salmon for subsistence (ADF&G Division of Subsistence, Community Profile Database 2003). Salmon is widely shared within the community; other households give salmon to households that are unable to harvest their own salmon. Household survey interviews were conducted by ADF&G Division of Subsistence in Angoon in the winter of 2002 and will provide updated information on subsistence harvest and use patterns in the community when published in the Subsistence Division database later this year (M. Kookesh ADF&G, personal communication 2003).

Table 1. Household survey results for Angoon on use and harvest of subsistence salmon (ADF&G Div. of Subsistence, Community Profile Database, 2003).

	Sockeye Salmon		**All Salmon**	
Year	Households using (%)	Households harvesting (%)	Households using (%)	Households harvesting (%)
1984	31.6	23.7	78.9	71.1
1987	51.5	28.8	85.4	63.5
1996	67.6	50.0	79.7	64.9

Subsistence fishing permits are issued by ADF&G Division of Commercial Fisheries; permit holders are required to report their harvest, and the division compiles effort and harvest data in its regional database. In the past decade, reported subsistence sockeye salmon harvest and effort have increased at Kanalku, and decreased at Basket Bay and Sitkoh (Table 2). There are many factors, which may contribute to these trends, including improved reporting in recent years, and a decrease in the amount of subsistence salmon taken in the commercial fisheries. The community of Angoon responded to low abundance of sockeye salmon at Kanalku in 2001 by instituting a voluntary fishing closure there in 2002. Some effort was shifted to Sitkoh and Basket Bays; however, harvesting sockeye salmon in Sitkoh Bay without the use of power seine gear appears to be difficult (M. Kookesh, ADF&G, personal communication 2002).

Table 2. Subsistence effort and harvest of sockeye salmon reported on permits from 1985-2001 at Kanalku, Kook, and Sitkoh (ADF&G Division of Commercial Fisheries database 2003).

System	Year	Number of Permits	Total Sockeye Harvested	Average Sockeye per Permit
Kanalku	1985	22	473	22
	1986	37	931	25
	1987	20	645	32
	1988	10	258	26
	1989	16	425	27
	1990	30	762	25
	1991	22	556	25
	1992	21	571	27
	1993	32	901	28
	1994	42	1282	31
	1995	39	936	24
	1996	59	1627	28
	1997	56	1538	27
	1998	53	1482	28
	1999	57	1666	29
	2000	50	1443	29
	2001	40	976	24
Average, all 17 yrs:		36	969	27
Average, since 1992:		45	1242	28
Kook	1985	37	450	12
	1986	78	1427	18
	1987	55	1233	22
	1988	30	316	11
	1989	35	493	14
	1990	32	477	15
	1991	25	341	14
	1992	34	602	18
	1993	27	475	18
	1994	22	328	15
	1995	21	387	18
	1996	20	302	15
	1997	18	187	10
	1998	19	327	17
	1999	21	308	15
	2000	18	234	13
	2001	23	269	12
Average, all 17 yrs:		30	480	15
Average, since 1992:		22	342	15
Sitkoh	1985	40	313	8
	1986	48	677	14
	1987	36	636	18
	1988	25	322	13
	1989	16	248	16
	1990	18	181	10
	1991	0	0	-
	1992	1	90	90
	1993	0	0	-
	1994	2	36	18
	1995	1	10	10
	1996	3	50	17
	1997	6	60	10
	1998	2	16	8
	1999	6	36	6
	2000	7	56	8
	2001	16	261	16
Average, all 17 yrs:		13	176	17
Average, since 1992:		4	62	20

Commercial and Sport Fisheries

Commercial fisheries began in Chatham Straits in the 1890s (Table 3). Sockeye salmon were the only species taken by canneries during the first decade, but since there was no large sockeye runs in the Chatham district, the expansion of the commercial fishing industry there depended upon the exploitation of the more abundant pink and chum salmon. The first major pink salmon harvest in 1901 was in northern Chatham Strait; within a few years, the number of canneries in the district had increased, and fish traps were in use. Depletion of the salmon resource, especially small sockeye runs in the bays along Chatham, led to commercial fishing legislation and the first closures in most of these bays, beginning in 1925 (Rich and Ball 1933).

Table 3. Historic records of commercial sockeye salmon harvest from Basket Bay, Sitkoh Bay, and Kootznahoo Inlet (the latter includes Kanalku Bay and other areas within Mitchell Bay; Rich and Ball 1933).

	Total Sockeye Harvest		
Year	**Basket Bay**	**Sitkoh Bay**	**Kootznahoo Inlet**
1890	-	4,902	-
-	-	-	-
1895	-	4,260	-
1896	21,175	15,794	-
1897	-	566	-
-	-	-	-
1900	61,500	30,000	-
-	-	-	-
1904	86,000	12,000	-
-	-	-	-
1912	2,968	-	-
-	-	-	-
1918	314	833	587
1919	-	-	563
1920	892	-	102
1921	-	552	3,058
1922	523	3,462	1,291
1923	910	-	-
1924	221	234	-
1925	-	248	458
1926	962	337	896
1927	2,340	122	601

The modern commercial fishery in northern Chatham Strait is primarily purse seining. Seining occurs in areas adjacent to Kootznahoo Inlet, Basket Bay, and Sitkoh Bay, and some sockeye salmon destined for these systems are taken incidentally, but it is impossible to distinguish specific runs among the catch. It is also assumed that most of the Kanalku sockeye salmon are avoided because the commercial fishery opens after their relatively early run into Kootznahoo Inlet and Kanalku Bay (A. McGregor ADF&G, personal communication 2001). The average annual sockeye harvest in sub-districts 112-11 and 112-12 (west side, from Peril Strait to Tenakee Inlet, and adjacent to Sitkoh Bay), 112-17 and 112-18 (east side, along Admiralty Island, and adjacent to Kootznahoo Inlet), and 112-13, 112-14 and 112-16 (east and west side from Freshwater Bay to Icy Strait) remained steady from 1960 through the late 1980s, and has increased substantially since 1989 (Figures 2, 3). Subdistrict 112-16, along Admiralty Island across from Icy Strait, was by far the largest producer, contributing about 75%, on average, of the total harvest. Many of these sockeye salmon are undoubtedly from large, mainland river runs. Sub-district 112-12, adjacent to Sitkoh and Basket Bays, along the west side of Chatham Strait, has contributed an average 10% of the total northern Chatham sockeye harvest, but since 1989 the average contribution has decreased to about 8%. Harvests from the two sub-districts directly to the north, 112-13 and 112-14 (Freshwater Bay to Icy Strait) have increased to 14% of the total since 1989 (ADF&G Division of Commercial Fisheries database 2003).

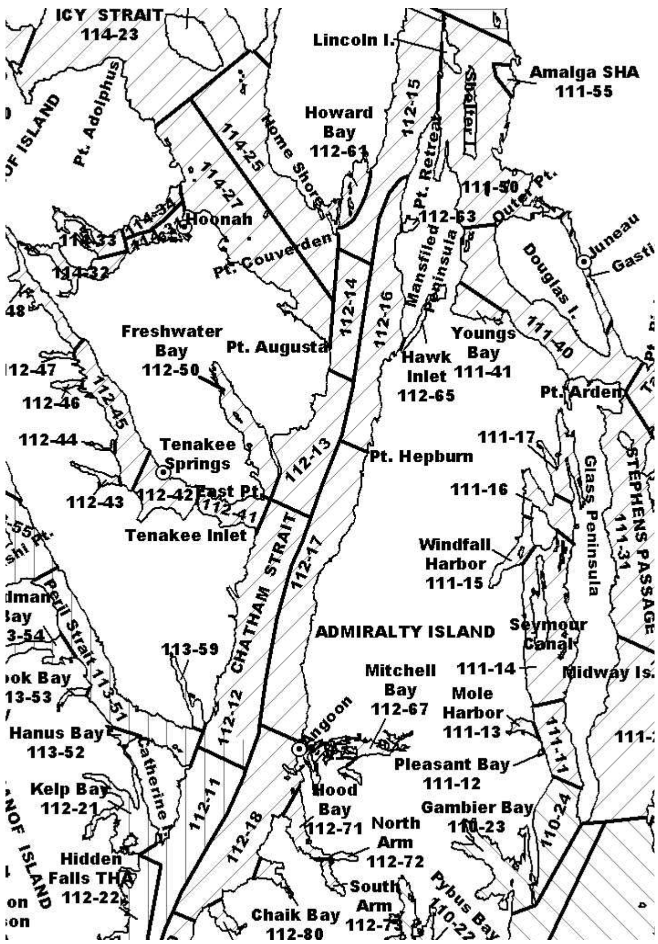

Figure 2. Map showing salmon fishery districts 112-11, -12, -13, -14, -16, -17, and -18 in northern Chatham Strait adjacent to Angoon area sockeye salmon systems.

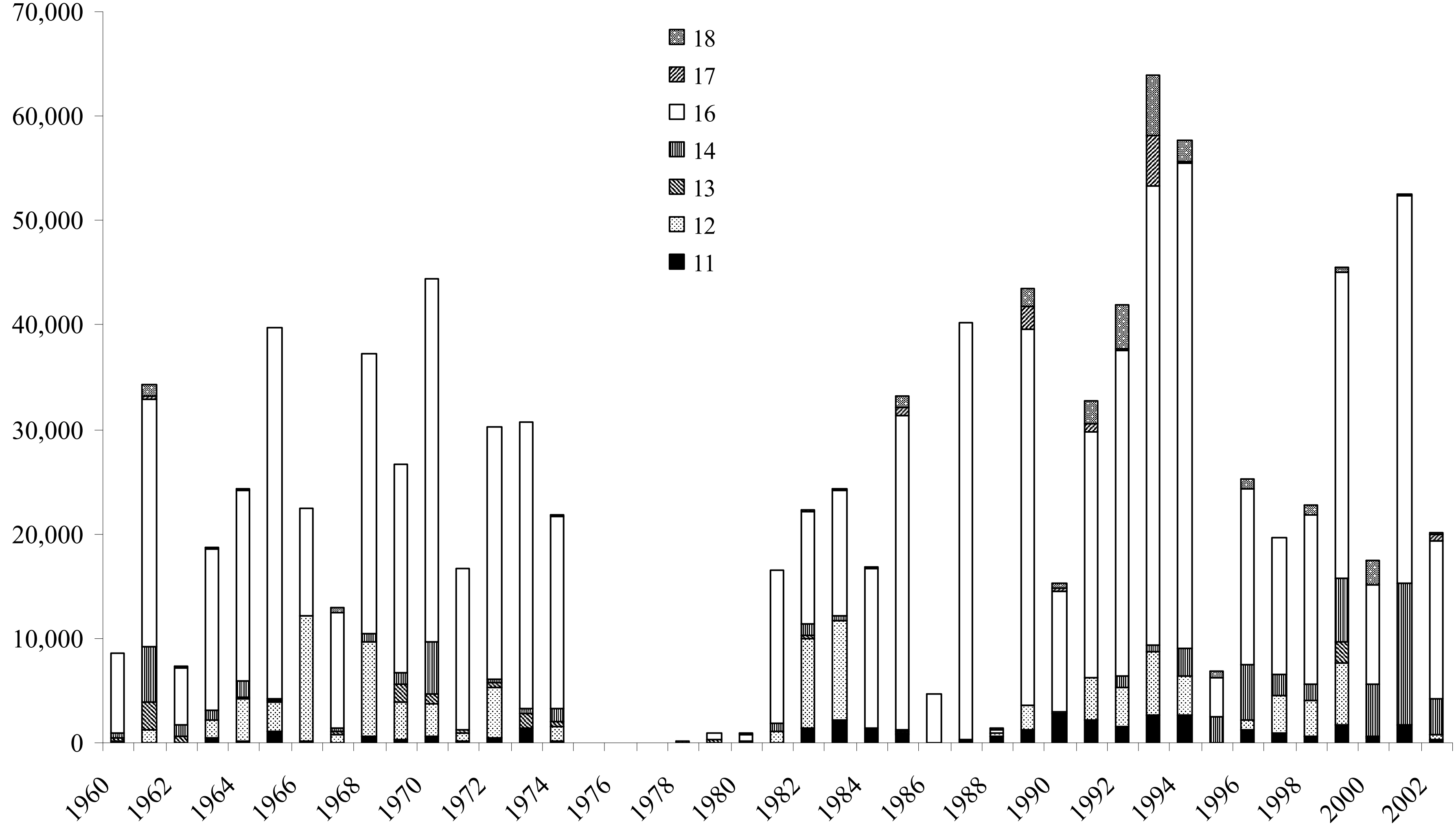

Figure 3. Commercial sockeye harvest in northern Chatham Strait (sub-districts 112-11, 112-12, 112-13, 112-14, 112-16, 112-17, and 112-18), from 1960-2002. Sub-districts 112-11 and 112-12 are adjacent to Sitkoh and Basket Bays, and sub-districts 112-17 and 112-18 are adjacent to Kootznahoo Inlet. Purse seining accounts for nearly all harvest (ADF&G Division of Commercial Fisheries database 2003).

Very limited data are available on sockeye harvest in the sport and charter fisheries. Effort and harvest are estimated from voluntary responses to ADF&G Sport Fish mail surveys (Table 4). Sockeye salmon are generally not targeted in the sport fisheries, but are instead caught incidentally and released. In general, sport-fishing effort is very low in these systems, and few if any sockeye salmon are caught. However, in a few years, high sport catches of sockeye salmon approached, or in one case, exceeded the total subsistence sockeye harvest in a given system. Sport and subsistence fishers compete directly for salmon in the terminal areas, so high sport catches or the perception thereof may cause concern to Angoon subsistence fishers. The Sitkoh system is a popular sport fishing area, with the third highest freshwater fishing effort in the Sitka area, and two U.S. Forest Service public use cabins on the lake (Yanusz 1997). There is also a Forest Service public use cabin at Kook Lake, but no salmon catches have been reported from freshwater in this system for over a decade. Most or all fishing activity in this system appears to be in the saltwater at Basket Bay. With the exception of freshwater areas at Sitkoh Bay and Lake, effort and catch estimates for these specific systems are based on fewer than 12 responses each, so the Division of Sport Fish advises that they should only be used to document that fishing occurred (ADF&G Division of Sport Fish database).

Table 4. Sport fishing effort and catch at Basket Bay/Kook Lake, Sitkoh Bay and Lake, and Kanalku Bay and Lake, estimated from statewide harvest survey responses (ADF&G Division of Sport Fish database 2003). Catch includes fish released as well as those kept.

				Estimated catch by species		
Area	**Year**	**No. of anglers**	**No. days fished**	**Chinook**	**Coho**	**Sockeye**
Basket Bay (saltwater)	1984	48	27	0	0	42
	1985	33	17	0	0	0
	1989	18	32	7	52	0
	1991	18	26	0	134	0
	1992	12	32	0	0	0
	1993	52	71	0	0	193
	1994	66	66	0	72	0
	1995	27	99	47	9	0
	1996	28	36	0	0	0
	1997	30	30	0	0	0
	1998	73	86	0	122	0
	1999	16	16	0	24	0
	2000	14	23	0	0	0
Sitkoh Bay (saltwater)	1988	57	57	0	0	0
	1992	12	12	0	0	0
	1993	11	11	0	0	0
	1994	64	131	0	66	0
	1995	13	27	9	0	0
	1996	73	110	11	0	0
	1998	76	122	67	76	0
	1999	80	102	12	0	0
	2000	40	40	0	0	0
	2001	58	153	12	114	366

Table 4. Continued - Sport fishing effort and catch at Basket Bay/Kook Lake, Sitkoh Bay and Lake, and Kanalku Bay and Lake, estimated from statewide harvest survey responses (ADF&G Division of Sport Fish database 2003). Catch includes fish released as well as those kept.

Area	Year	No. of anglers	No. days fished	Estimated catch by species		
				Chinook	Coho	Sockeye
Sitkoh Lake/Stream (freshwater)	1984	144	286	0	102	0
	1985	389	486	0	0	0
	1986	622	1072	0	23	0
	1987	501	642	0	0	7
	1988	340	367	0	0	0
	1989	263	555	0	0	0
	1990	392	694	0	0	0
	1991	301	795	0	0	0
	1992	187	437	0	146	0
	1993	480	1627	0	664	0
	1994	589	1257	0	0	9
	1995	145	360	0	0	0
	1996	109	109	0	40	0
	1997	212	590	0	59	170
	1998	256	401	0	0	258
	1999	526	1304	0	268	0
	2000	290	1064	0	0	0
	2001	253	1232	0	0	0
Kanalku Lake	1992	12	12	0	0	0
	1993	78	320	0	0	241
Kanalku Bay	1994	13	13	30	0	0

Ecological and Salmon Escapement Information

Escapement and biological data for Kanalku, Kook, and Sitkoh Lakes prior to the start of the subsistence sockeye salmon projects in 2001 are limited. Aerial survey counts were conducted opportunistically during other ADF&G Commercial Fisheries Division management surveys, but these surveys are not considered reliable estimates of sockeye salmon populations due to variation in visibility, timing, and observers (Jones and McPherson 1997; Jones et al. 1998; Conitz and Cartwright 2002a, b). Weirs were used at the outlet of Sitkoh Creek in the spring in 1936, 1937, 1982, 1990, and 1993, to count immigrating steelhead and emigrating cutthroat trout and Dolly Varden char (Yanusz 1997; Jones and Yanusz 1998; Brookover et al. 1999). In 1982 and 1996, ADF&G operated adult salmon escapement weirs on Sitkoh Creek. Mark-recapture studies on the spawning grounds were used to estimate sockeye escapement into Sitkoh Lake from 1996–2000. In 1999 and 2000, the mark-recapture methods used at Sitkoh were consistent with those used in the current project, yielding two additional years' reliable estimates to the current time series (Kelley and Josephson 1997; Cook 1998; Crabtree 2000, 2001; Conitz and Cartwright 2002a). An adult weir was operated at Kook Lake in 1994 and 1995 and sockeye salmon age, sex, and length samples were taken in those years and four additional years during the 1980s (Conitz and Cartwright 2002b).

In 2001 and 2002, a crew of U.S. Forest Service and Angoon Community Association employees cleared the Outlet Stream of Kook Lake of large deadfall and other debris, especially in cave entrances through which the stream passes. The partial barriers may have impeded sockeye salmon migration into Kook Lake for an unknown number of years (Conitz and Cartwright 2002b).

Lake ecology and limnology data were collected in single-year studies at Kanalku Lake in 1995 and Sitkoh Lake in 1992, and for three years in the 1990s at Kook Lake. Sockeye fry populations were estimated in 1994 and 1995 in Kook Lake, and in 1995 in Kanalku Lake using hydroacoustic and tow net sampling. Populations of emigrating sockeye salmon smolt were estimated at Kook Lake in 1994 and 1995 using weirs (Conitz and Cartwright 2002a, b). Data on lake ecology and juvenile and adult sockeye salmon were collected and analyzed under the current project in 2001 for Kanalku, Sitkoh (Conitz and Cartwright 2002a) and Kook Lakes (Conitz and Cartwright 2002b).

Issues and Concerns

Angoon subsistence users and ADF&G biologists have expressed concern about the extremely small sockeye escapement into Kanalku Lake in 2001 (Conitz and Cartwright 2002a), and action was taken within the Angoon community during the 2002 season to protect this run. Since the mid-1980s, there have been concerns about low sockeye returns to Kook Lake which, combined with lack of information, have resulted in commercial, sport, and subsistence fishery closures (ADF&G Emergency Orders; A. McGregor ADF&G, personal communication 2002). Efforts to clear obstructions from the Kook Lake outlet stream in 2001 and 2002 may be helping to restore this run. During recent years, sockeye runs in Sitkoh Lake appear to be healthy and may provide an alternate resource for Angoon subsistence users (Conitz and Cartwright 2002a).

This report covers the second year of an ongoing, three-year project. Data collection in 2002 included an assessment of each lake's physical characteristics, and zooplankton species composition, density, and biomass. Fry density, size, and age were estimated to provide indicators of sockeye salmon response to conditions within each lake. Adult escapement was estimated using mark-recapture methods and visual surveys, with additional estimates of age, sex, and length composition. Building on earlier work at Sitkoh Lake, we now have four years of continuous and reliable escapement estimates. With estimates for two additional years, we will have information covering the span of at least one sockeye generation.

These results support the long-term objective of setting escapement goals that incorporate lake productivity modeling. If extended over a 5-10 year time period, this type of data collection effort will provide fisheries managers with the quantitative information they need to set escapement goals and ensure that these important salmon resources continue to provide sustainable fishing opportunities into the future.

OBJECTIVES

1. Estimate the annual sockeye escapement into Kanalku, Kook, and Sitkoh Lakes, using mark-recapture methods and observer counts on the spawning grounds, so that the estimated coefficient of variation is less than 15%.
2. Estimate the age, length, and sex composition of the sockeye salmon in the escapement at each lake, so that the estimated coefficient of variation is less than 5%.
3. Estimate the productivity of each lake using established ADF&G limnological sampling procedures.
4. Estimate the sockeye fry rearing density within each lake so that the estimated coefficient of variation is less than 10%.

A 95% confidence interval will be reported for these population estimates, where appropriate.

METHODS

Study Sites

Kanalku Lake

Kanalku Lake (N 57°29.22' W 134°21.02') is about 20 km southeast of Angoon and lies in a steep mountainous valley within the Hood-Gambier Bay carbonates ecological subsection (Nowacki et al. 2001). Carbonate bedrock and soils built up on rounded mountainsides and in U-shaped valleys support a highly productive spruce forest in the watershed, especially where there are major colluvial and alluvial fans. The watershed area is approximately 32 km^2, with one major inlet stream draining into the east end of the lake. The lake elevation is about 28 m, and has a 1.7 km outlet stream that drains into the east end of Kanalku Bay. The lake surface area is about 113 hectares, the mean depth is 15 m and the maximum depth is 22 m (Figure 4). In addition to the sockeye salmon run (*Oncorhynhcus nerka*), a large number of pink salmon (*O. gorbuscha*) spawn in the lower part of the outlet creek and intertidal area. A few coho (*O. kisutch*) and chum salmon (*O. keta*) spawn in the Kanalku system, and resident populations of cutthroat trout (*Oncorhynchus clarki* spp.), Dolly Varden char (*Salvelinus malma*), and sculpin (*Cottus sp.*) are found in Kanalku Lake. A waterfall, approximately 8–10 m high and about 0.8 km upstream from the tidewater forms a partial barrier to migrating sockeye salmon. The U.S. Forest Service considered constructing a fishpass over the falls in the 1960s but finally recommended against it due to cost. In 1970 ADF&G, working with the U.S. Forest Service, blasted resting pools and a small channel in the falls bedrock to assist the migrating salmon.

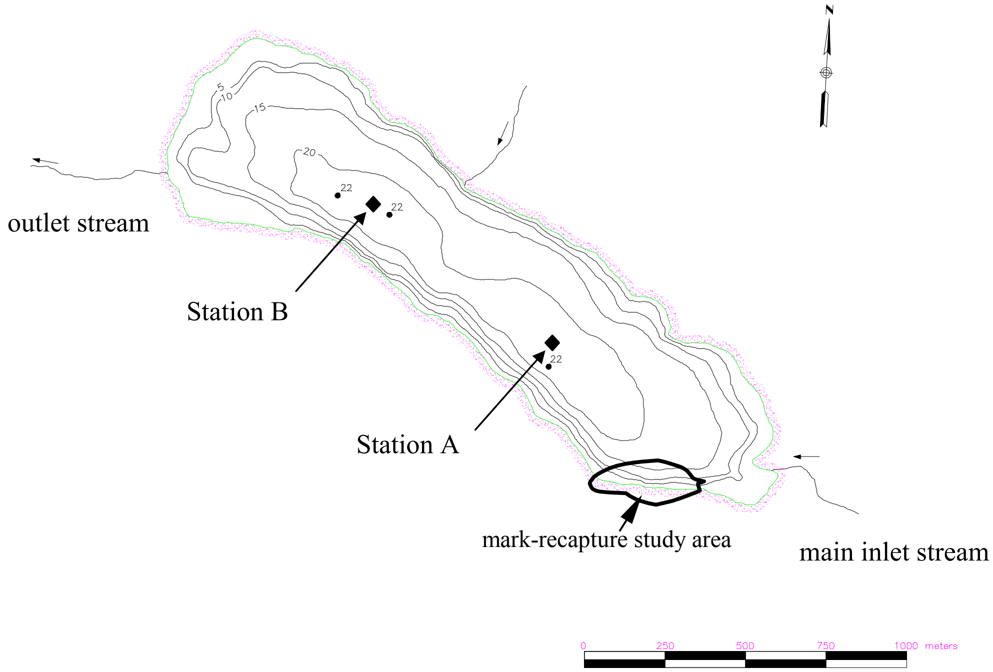

Figure 4. Bathymetric map of Kanalku Lake, showing 5 m depth contours, mark-recapture study area, and two permanent limnology sampling stations (A and B).

Kook Lake

Kook Lake (N 57°39.86', W 134°57.25') is across Chatham Strait from Angoon, about 26 km to the northeast, and on the east side of Chichagof Island. Its watershed lies within the Kook Lake carbonates ecological subsection (Nowacki et al. 2001). Past glaciations over the entire area has rounded the mountains and created cirque basins such as the one containing Kook Lake. The total drainage area is about 54 km^2 and there are two main inlet streams entering the southwest end of the lake. Kook Lake has a surface area of about 240 ha, a mean depth of 30 m, and a maximum depth of 44 m (Figure 5). The lake lies at an elevation of about 123 m, and has a 2 km outlet stream, Kook Creek, that flows into Basket Bay on Chatham Strait. Three natural caves, each about 150-300 m long, have formed in the carbonate bedrock along the Kook Creek channel, and salmon swim through these on their way up to the lake to spawn. In addition to sockeye salmon, the lake supports runs of coho, chum, and pink salmon; resident fish include Dolly Varden char, cutthroat trout, threespine stickleback (*Gasterosteus aculeatus*), and sculpin. The Kook Lake watershed is extensively clear-cut and crossed by a logging road system, which connects with the Corner Bay logging camp in Tenakee Inlet.

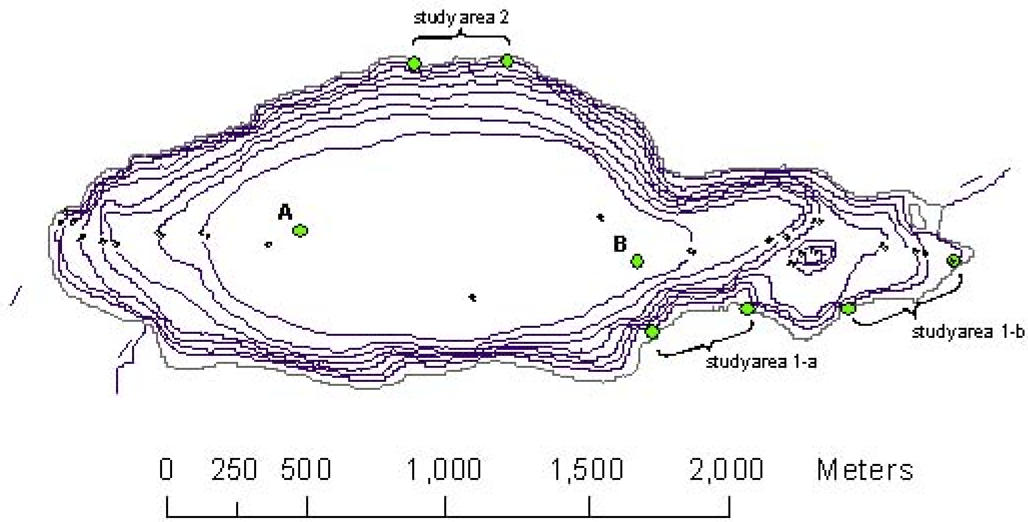

Figure 5. Bathymetric map of Kook Lake, showing 5 m depth contours, two permanent limnology sampling stations (A, B), and three mark-recapture study areas (1a, 1b, 2).

Sitkoh Lake

Sitkoh Lake (N 57°30.89', W 135°2.52') is located on the southeastern tip of Chichagof Island, about 30 km from Angoon, and drains east into Sitkoh Bay. Situated between Chatham and Peril Strait, the Sitkoh Lake drainage lies within the Peril Strait granitics ecological subsection, while the outlet stream and the bay are part of the Kook Lake carbonates subsection to the east (Nowacki et al. 2001). Continental ice sheets covering this area left rounded and heavily scoured mountains. Sitkoh Lake and its outlet stream lie in a broad, U-shaped valley that nearly bisects the peninsula at the tip of Chichagof Island. The Sitkoh Lake watershed area is about 31 km^2; the lake is situated at an elevation of about 59 m. Its surface area is 189 hectares, the average depth is 20 m, and the maximum depth is 39 m (Figure 6). Several steep-gradient inlet streams enter the lake on the north and south sides, ending in productive alluvial fans on the lakeshore; the outlet stream is about 6 km long with at least two tributaries. The lake supports runs of sockeye, coho, pink, and chum salmon. It also supports a large run of as many as 50,000 anadromous Dolly Varden char, several thousand sea-run cutthroat trout and a smaller number of summer resident cutthroat trout, and one of the region's largest steelhead (*Oncorhynchus mykiss*) runs at around 500-1100 fish, (Yanusz 1997, Jones and Yanusz 1998, Cook 1998, Brookover et al. 1999). The Sitkoh drainage was extensively clear-cut between 1969 and 1974.

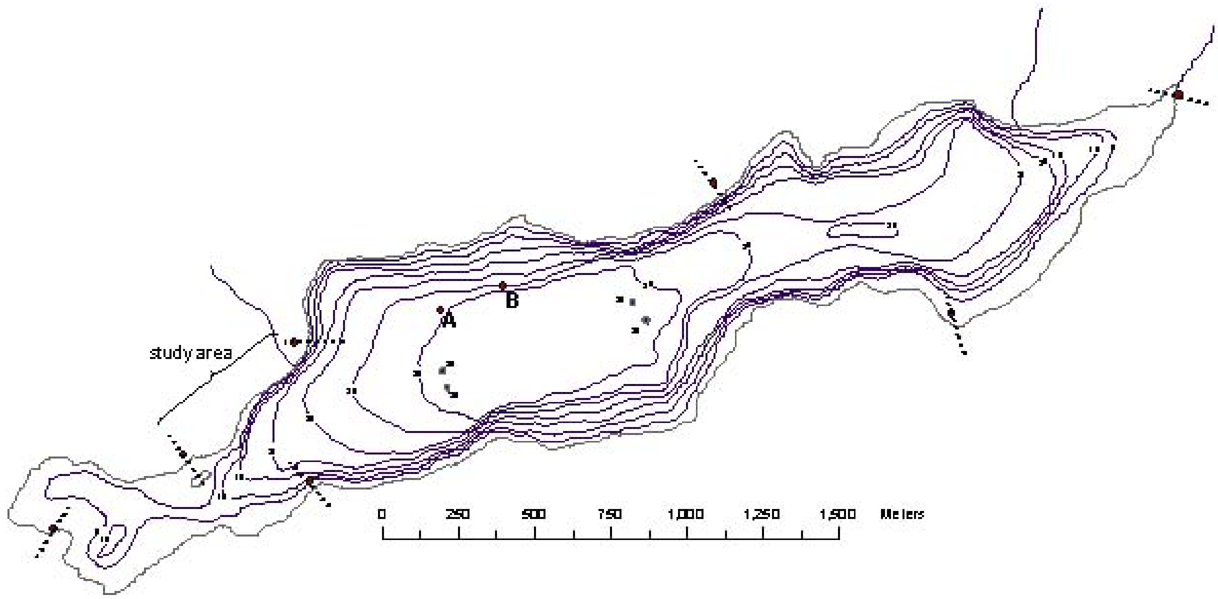

Figure 6. Topographic map of Sitkoh Lake, showing two permanent limnology sampling stations (A, B), mark-recapture study area, and boundaries of lake survey areas.

Juvenile Sockeye Population Assessment

Sockeye Fry Population Estimates

Hydroacoustic and mid-water trawl sampling were used to estimate the distribution and abundance of sockeye salmon fry in Kanalku, Kook, and Sitkoh Lakes. Prior to conducting the 2002 lake survey, each lake was divided into six sections based on lake area and shape. Ten evenly spaced orthogonal transects were identified within each section and two of these were randomly selected to be surveyed. Transects selected in 2002 became permanent and will be repeated during future surveys. The decision to keep the transects fixed each year reflected a decision to emphasize year-to-year changes in population size in our estimates.

Hydroacoustic Survey

During the acquisition of acoustic targets, we surveyed each selected transect from shore to shore, beginning and ending the sampling at the depth of 10 m. Sampling was conducted during the darkest part of the night. A constant boat speed of about 2.0 m · sec^{-1} was attempted for all transects. The acoustic equipment consisted of a Biosonics[2] DT-4000™ scientific echosounder (420 kHz, 6° single beam transducer). Biosonics Visual Acquisition© version 4.0.2 software was used to collect and record the data. Ping rate was set at 5 pings · sec^{-1} and pulse width at 0.4 ms.

Only target strengths ranging from –40 dB to –68 dB were recorded because this range represented fish within the size range of juvenile sockeye salmon and other small pelagic fish.

Trawl Sampling

Midwater trawl sampling was conducted in conjunction with the hydroacoustic surveys to determine the species composition of pelagic fish and the age distribution of sockeye fry. A 2 m x 2 m elongated beam-trawl net with a cod-end was used for the trawl sampling. Trawl sampling was conducted in the area of the lake with the highest concentration of fish, identified during the hydroacoustic survey. An exploratory surface tow was conducted to determine if there were fish on the surface not detected by the down-looking hydroacoustic gear. A surface tow was conducted on clear and stained lakes and will not be repeated in future surveys if no fish were caught. The surface tow was conducted by attaching floats to the top of the tow net so that it floated just beneath the lake surface 30 m back from the boat. Additional tows were conducted at two depths, also identified during the hydroacoustic survey in the same area of highest fish concentration. Two replicate tows were conducted at each depth. The second tow at a given depth was started at the termination point of the first tow. The direction of the second tow for each depth was selected such that it did not sample the same area as the first tow. The trawl duration ranged from 15 to 30 minutes, depending on fish density and lake size and morphology. If warranted, a second complete set of tows was conducted in a morphologically distinct section of the lake or in a second area of high fish densities.

All adult fish caught in the midwater trawl were identified, counted, and released. All small fish from the trawl net were euthanized with MS 222. Fish were preserved with 90% alcohol. Samples from each tow were preserved in separate bottles. The bottle was labeled with the date, lake name, tow number, tow depth, time of tow, and initials of collectors. Fish captured in the tow samples were analyzed at the laboratory to determine species composition and ages of sockeye juveniles. The species composition of the midwater trawl samples was pooled and applied to the total target estimate to calculate each species-specific population estimate. The sockeye fry density and age composition was also calculated using the sockeye fry trawl sample data.

In the laboratory, fish were soaked in water for 60 minutes before sampling to re-hydrate the samples. All fish were identified and the snout-fork length (to the nearest millimeter) and weight (to the nearest 0.1 gram) were measured on each fish. All sockeye salmon fry under 50 mm were assumed to be age-0. Scales were collected from sockeye fry over 50 mm and mounted onto a microscope slide for age determination. Sockeye fry scales were examined through a Carton microscope with a video monitor and aged using methods outlined in Mosher (1968). Two trained technicians independently aged each sample. The results of each independent scale ageing were compared. In instances of discrepancy between the two age determinations, a third independent examination was conducted. A proportion of each age class of sockeye fry is used to allocate the hydroacoustic sockeye fry estimates by age. Data was recorded onto a form and then entered into an MS Excel spreadsheet.

Data Analysis

Data was analyzed using Biosonics Visual Analyzer© version 4.0.2 software. Echo integration was used to generate a fish density (targets $\cdot$ m^{-2}) for each of the sample sections (MacLennand and Simmonds 1992). The target density for each section was estimated as the mean of these two replicate target densities, with their sample variance. The mean target density for the whole lake was estimated as the average of target density estimates for each section weighted by surface area of each section. A target population for each sample section was estimated as the product of mean target density and surface area for each section. The total target population for the lake was estimated as the sum of target population estimates for each section. Because each section was sampled independently from other sections, the estimated sampling variance for the whole lake target population estimate was simply the sum of the variances for each section, and was reported as a coefficient of variation (CV; Sokal and Rohlf 1987). If the CV for an estimate was greater than 10% for any of the lakes, more sample sections will be added in that lake in future years.

The apportionment of targets into species composition categories allowed us to get a rough estimate of sockeye fry abundance in those lakes where we had adequate trawl data. An obvious way to estimate the sockeye fry abundance in the entire lake is to simply pool all fish caught in all trawl samples (except the surface tow) into one sample, calculate the proportion of sockeye fry in the pooled sample, and then use this proportion to adjust the estimate of total sonar targets in the lake to an estimate of total sockeye fry. Although this approach should give a reasonable and very usable estimate of the number of sockeye juveniles present in the lake, unfortunately, this approach leaves us without a means to estimate the sampling error in the estimate.

We first assumed that sockeye fry are completely randomly distributed within the lake, and therefore within the multiple trawl samples. If so, we reasoned that the estimate of sampling error could be based on an approximation to the binomial distribution, which is well studied, and formulas for confidence intervals or standard errors can be found in any elementary statistical textbook. We began by developing rules for sample size requirements and using chi-squared tests for heterogeneity to test for similarity among trawl samples. We reasoned that if we had greater than 30 fish targets per trawl sample, if the assumptions of the chi-squared test we met (greater than 5 expected counts per cell and a fairly uniform distribution), that small observed chi-squared statistics would mean that the binomial approximation would be a usable assumption. However, we found that we had inadequate sample sizes to compare trawls at the same depth with these chi-squared tests. When we pooled the samples into one or more depth categories, in general we got small chi-squared statistics with small sample sizes and lager chi-squared statistics with larger sample sizes. In the end, we concluded that a simple, defendable estimate of the variance associated with the estimate of the proportion of sockeye fry is not possible because of the non-uniform distribution of sockeye fry in the lake, the clustering of sockeye fry within the samples and the small sample sizes. If we assume that the distribution is clumped, a negative binomial distribution to account for the clusters could be used if we had adequate trawl samples at each depth.

Adult Escapement Estimates

Spawning Grounds Mark-Recapture and Visual Survey

Mark-recapture methods, designed for beach-spawning areas, were used to estimate a portion of the sockeye salmon spawning escapement in Kanalku, Kook, and Sitkoh Lakes. A study area was designated where the majority, or a representative group, of spawners congregated, and mark-recapture sampling was conducted only within this area. Sockeye salmon were counted visually in surveys around the shoreline of each lake. Separate counts were recorded within the study area, in order to give a rough estimate of the proportion of escapement included within the mark-recapture study areas. In these three systems, escapement estimates include only those sockeye salmon spawning along beach or shoreline areas of the lake, and exclude any sockeye salmon spawning in inlet or outlet streams. Observations in this and previous seasons indicate that there are few, if any, stream spawners in any of these systems. In Kanalku Lake, most of the sockeye salmon spawn along a section of the shoreline near the inlet stream, but we have observed no sockeye salmon in the inlet stream itself. Kook Lake is known to have an inlet stream spawning population, but fish were not seen in the inlet in 2001 and in 2002 we observed spawners there for only a brief period early in the season. These inlet stream spawners may arrive and spawn earlier than those spawning around the lakeshores. In Sitkoh Lake, only beach-spawning sockeye salmon have been observed.

ADF&G biologists have modified the methods described in Schwarz et al. (1993) for estimating salmon escapements in beach spawning systems (Cook 1998). Specifically, we used a two-sample Petersen estimate for each trip and a multiple-trip estimate using a modified Jolly-Seber method to estimate the number of spawners returning across all trips (Seber 1982; Schwarz et al. 1993; Cook 1998; J. Blick former ADF&G, personal communication 1998).

<u>Visual Survey Counts of Sockeye Spawners</u>

Prior to each mark-recapture event, visual counts of sockeye spawners were made by each crewmember in defined strata around the entire lakeshore and in any inlet stream where spawners were present. A separate count was made within the "study area" or areas designated for the mark-recapture study. Any inlet stream with sockeye spawners present was defined as a separate stratum. We attempted to have at least three observers for each survey. Each crewmember recorded his or her own count separately. The counts gave a rough indication of the proportion of sockeye spawners within the defined study area at each sampling event.

<u>Mark-Recapture Methods for Beach Spawning Populations</u>

The study design consisted of two stages: 1) a two-sample Petersen estimate for each trip (Seber 1982) and 2) a multiple-trip estimate using a modified form of the Jolly-Seber method for multiple mark-recaptures in an open population (Seber 1982; Schwarz et al. 1993; Cook 1998). In the first stage, fish were marked on one day and examined for marks the next day. In the second stage, fish caught on both days of a given trip were given a unique mark for that trip. Then on subsequent trips recaptures of these marks were recorded. In the second stage we used the number of recaptures from each previous trip, together with the first-stage Petersen estimates of abundance from each trip, to generate an estimate of fish that spawned within the study area over the entire season.

A 20 m long x 4 m deep beach seine was used to surround sockeye salmon, pulled by a small skiff with outboard motor and crewmembers on foot. All sockeye salmon caught were first inspected for previous marks, then marked with an opercular punch or pattern of punches indicating the trip and day number, and released with a minimum of stress. The total sample size, the number of new fish marked, and the number of recaptured fish with each type of mark were recorded. Sampling in these small populations continued until the number of same-day recaptures exceeded the number of new fish caught. Right opercular punches were the primary mark for each trip as follows: trip 1 – round, trip 2 – triangle, trip 3 – square, trip 4 – two round. A left opercular punch (any shape) was given each fish caught on the second day of each trip to indicate the fish had already been caught and should not be recounted on that trip.

Data Analysis

Chapman's form of the Petersen mark-recapture estimate was used for the first-stage, "instantaneous" population estimates within the study area (Seber 1982, p. 60). We let *K* denote the number of fish marked in a random sample of a population of size *N*. We let *C* denote the number of fish examined for marks at a later time, and let *R* denote the number of fish in the second sample with a mark. Then the estimated number of fish in the entire population, $\hat{N}$, is given by

$$\hat{N} = \frac{(K+1)(C+1)}{(R+1)} - 1. \tag{1}$$

In this equation, *R* is a random variable, and it can be assumed to follow a Poisson, binomial, or hypergeometric distribution, depending on the circumstances of the sampling. Moreover, when *R* is large compared with the size of the second sample, *C*, its distribution can be assumed to be approximately normal (a practical check is to ensure *R* is at least 30 before using the normal approximation). Let $\hat{p}$ be an estimate of the proportion of marked fish in the population such that $\hat{p} = \frac{R}{C}$. We used approximate confidence interval bounds for $\hat{p}$ based on the assumption that *R* follows a hypergeometric distribution. We defined the confidence bounds for $\hat{p}$ as ($a_{0.025}$, $a_{0.975}$). Then the 95% confidence interval bounds for the Petersen population estimate, *N**, were found by taking reciprocals of the confidence interval bounds for $\hat{p}$, and multiplying by *K*. That is, the confidence bounds for the Petersen estimate are given by ($K * 1/a_{0.975}$, $K * 1/a_{0.025}$).

Sample size criteria are given in Seber (1982, p. 63). If $\hat{p} \geq 0.1$, and the size of the second sample *C* is at least the minimum given in Table 5, a 95% confidence interval for $\hat{p}$ is given by

$$\hat{p} \pm \left[1.96 \sqrt{\left(1 - \frac{C}{\hat{N}}\right) * \hat{p}(1-\hat{p})/(C-1)} + \frac{1}{2C} \right], \text{ (Seber 1982, eq. 3.4).} \tag{2}$$

Table 5. Sample size criteria for using Seber's (1982) eq. 3.4 to find 95% confidence interval for $\hat{p}$. For given $\hat{p}$, minimum sizes for the second sample C are indicated.

$\hat{p}$ (or 1-$\hat{p}$)	0.5	0.4	0.3	0.2	0.1
minimum C	30	50	80	200	600

Seber's (1982) eq. 3.4 was also used when $\hat{p} < 0.1$ if $R > 50$. If these criteria were not met, the confidence interval bounds for $\hat{p}$ were found from Table 41 in Pearson and Hartley (1966).

In the second-stage estimation process, the first-stage Petersen estimates were used to estimate the total spawning population within the study area, N^*. Given s sampling occasions, we let $\hat{N}_i$ denote the first-stage Petersen population estimate from each sampling occasion i. The $\hat{N}_i$ values were used in place of the Jolly-Seber-derived parameter estimates of the number of animals alive in the system at each sampling occasion (J. Blick ADF&G, personal communication 1998; Cook 1998). We let n_i represent the number of unmarked fish and fish marked on previous trips, caught at sampling occasion i, and we let m_i represent the number of fish marked on previous trips, caught at sampling occasion i.

We also defined the following parameters (Schwarz et al. 1993; J. Blick ADF&G, personal communication, 1998; Cook 1998):

M_i = number of marked fish alive at time i,
ϕ_i = probability that a fish alive at time i is also alive at time i+1 (*i.e.* the survival rate)
B_i = number of fish that enter the system after occasion i and are still alive at time i+1 (*i.e.* immigration).
B_i^* = number of fish that enter the system after occasion i, but before occasion i+1,
N^* = total number of animals that enter the system before the last sampling occasion.

M_i was estimated as $\hat{M}_i = m_i \hat{N}_i / n_i$, for $i = 1, \ldots, s$;

ϕ_i was estimated as $\hat{\phi}_i = \hat{M}_{i+1} / (\hat{M}_i - m_i + n_i)$, for $i = 1, \ldots, s$-1;

B_i was estimated as $\hat{B}_i = \hat{N}_{i+1} - \hat{\phi}_i \hat{N}_i$, for $i = 1, \ldots, s$-1;

B_i^* was estimated as $\hat{B}_i^* = \hat{B}_i \log(\hat{\phi}) / (\hat{\phi} - 1)$, for i = 2,…..,s-1, and

N^* was estimated as $\hat{N}^* = \sum_{i=0}^{s-1} \hat{B}_i^*$.

Recruitment and mortality were assumed to be uniform between times i and i+1. Because B_0^* and B_1^* are not uniquely estimable, $\hat{B}_0^* + \hat{B}_1^*$ was estimated by $\hat{N}_2 \log(\hat{\phi})/(\hat{\phi}-1)$.

A parametric bootstrap method (Buckland 1985 and 1984) was used to construct confidence intervals for the parameter estimates in both stages. Let each bootstrap step be indexed by j (j=1...G; for our purposes G=1,000). The parametric bootstrap distribution for $\hat{N}_i$ was developed by drawing G bootstrap observations of a hyper geometrically distributed random variable (that is, r_i) using parameters based on the observed values of C_i, K_i, and $\hat{N}_i$ at each sampling event i. At each step $\hat{N}_i(j)$ is developed as previously described. Denote each bootstrap observation in the first estimation stage as the pair of $r_i(j)$ and $\hat{N}_i(j)$, for j = 1...G. Before proceeding on to the simulation of the second stage (the Jolly-Seber portion), the variance of the number of recaptures across all bootstrap replicates was calculated and denoted sb_i, for each trip i (*i.e.*, $\text{Var}_j(r_i(j)) = sb_i$). Note that this standard deviation is calculated from the bootstrap distribution of just the recaptures from the previous-day's marking event. To simulate the Jolly-Seber portion, for each bootstrap step, a bootstrap observation, $m_i(j)$, was drawn from a normal distribution with the mean determined from the actual observed value of m_i, and the standard deviation given by sb_i. Because this standard deviation is based on the simulated variability in just the previous-day's marking, it may tend to understate the sampling variability of m_i, which is the number of recaptures from all previous marking events. Even so, this assumption should provide a sensible approximation. We condition on the sample size, which we assume to be fixed and not a random variable, so that $n_i = n_i(j)$, for all j bootstrap observations. We then estimate $\hat{M}_i(j)$, $\hat{\phi}_i(j)$, and so on, as previously described, for all j = 1, ...G. The confidence interval for each parameter estimate is found from the quantiles of the bootstrap distribution (Rice 1995) for that estimate.

Adult Sockeye Salmon Population Age and Size Distribution

Scales, matched with sex and length data, were collected from adult sockeye salmon on the spawning grounds in Kanalku, Kook, and Sitkoh Lakes to describe the age and size structure of each population. The sampling goal for each lake was 600 fish. All unmarked sockeye salmon were sampled on the first day of each sampling trip, until the trip goal of 200 samples was reached. Three scales were taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were analyzed at the ADF&G salmon aging laboratory in Douglas, Alaska. Age and length data were paired for each fish sample. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g. 1.3 denotes 1-year freshwater and 3-years saltwater) (Koo 1962). Brood year tables were compiled by sex and brood year to describe the age structure of the returning adult sockeye salmon population. The length of each fish was measured from mid-eye to tail fork to the nearest millimeter (mm).

After the scales were aged, the scale samples data were categorized by age and by sex. Let n be the total number of samples aged, n_k be the number of samples in stratum k, and N total escapement. Since total escapement was not known exactly, we used the estimated escapement for N. Let p denote the proportion in each category k. This proportion was estimated by,

$$\hat{p}_k = \frac{n_k}{n}. \tag{3}$$

The estimated standard error of $\hat{p}_k$ was derived from the binomial distribution with correction for finite population size (Thompson 1992, p. 35-36):

$$SE(\hat{p}_k) = \sqrt{\left(1 - \frac{n}{N}\right)\frac{\hat{p}_k(1-\hat{p}_k)}{n-1}} \tag{4}$$

The estimated mean length and associated standard error for stratum *k* were calculated as the sample mean of a simple random sample (Thompson 1992, p. 42-43):

$$\bar{y}_k = \frac{1}{n_k}\sum_{i=1}^{n_k} y_{ki} \text{ , and } SE(\bar{y}_k) = \sqrt{\frac{1}{n_k}}\sqrt{\left(\frac{1}{n_k - 1}\right)\sum_{i=1}^{n_k}(y_{ki} - \bar{y}_i)^2} \;. \tag{5}$$

It appears that the ADFG Age Laboratory did not use the finite population correction factor in the analysis of the length data. The authors will work with programmer to apply this factor in the future. However, the authors feel that the addition of this factor will not significantly change the results.

Limnology

Limnology sampling began in late May due to late ice cover in 2002, and was repeated at approximately six-week intervals through early October, for a total of four sampling dates. Two stations were sampled in each lake (Conitz and Cartwright 2002a). Physical data was taken only at Station A, the main basin or the deepest part of the lake. In lakes with only one basin, station A was or will be redesignated as the station nearest the inlet stream. Zooplankton samples were collected from both stations on each sampling date to get a replicate sample for each lake.

Light, Temperature, and Dissolved Oxygen Profiles

Underwater light intensity was recorded from just below the surface to the depth where measured intensity was one percent of the surface light reading, at 0.5 m intervals, using an electronic light sensor and meter (Protomatic). The vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (natural log of percent subsurface light) versus depth. The euphotic zone depth (EZD) was defined as the depth to which one percent of the subsurface light [photosynthetically available radiation (400-700nm)] penetrates the lake surface (Schindler

1971), and is calculated from the equation: EZD = 4.6205/ K_d (Kirk 1994). The euphotic zone depth defines the part of the lake where photosynthesis is possible.

Temperature and dissolved oxygen (DO) profiles were measured with a Yellow Springs Instruments (YSI) Model 58 DO meter and probe, in relative (%) and absolute (mg L^{-1}) values for DO and in ºC for temperature. Measurements were made at 1 m intervals to the first 10 m or the lower boundary of the thermocline (defined as the depth at which the change in temperature decreased to less than 1ºC per meter), and thereafter at 5 m intervals to within 2 m of the bottom (or 50 m). The dissolved oxygen meter reading at 1 m was calibrated at the beginning of a sampling trip using the value from a 60 ml Winkler field titration (Koenings *et al*. 1987). The DO profile was measured only on the first sampling trip in May in Kook and Sitkoh Lakes, and on the second trip, in early July, in Kanalku Lake.

Secondary Production

Zooplankton samples were collected at two stations using a 0.5 m diameter, 153 um mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a maximum depth of 50 m, or 2 m from the bottom of the lake if shallower than 50 m, at a constant speed of 0.5 m sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Zooplankton samples were analyzed at the ADF&G Commercial Fisheries Limnology Laboratory in Soldotna, Alaska. Identification to genus or species, enumeration, and density and biomass estimates were performed as in 2001 (Conitz et al. 2002; Koenings et al. 1987). Zooplankton density (individuals per m^2 surface area) and biomass (weight per m^2 surface area) were estimated by species and by the sum of all species (referred to as total zooplankton density or biomass).

RESULTS

Juvenile Sockeye Population Assessments

Sockeye Fry Population Estimates

<u>Kanalku Lake</u>

Hydroacoustic and trawl surveys were completed in Kanalku Lake on August 10. The total hydroacoustic target estimate was 28,700 fish (CV 17%). Only four fish were caught among all five tows, three sockeye salmon and one sculpin (Table 6). The sockeye fry were all under 50 mm in length and assumed to be age-0. Species apportionment for the hydroacoustic targets was assumed to be 75% age-0 sockeye salmon and 25% sculpin, based on these very limited samples. The estimated total population of sockeye fry was about 21,500, and the estimated density of sockeye fry in the lake was 0.03 fry · m^{-2} (Table 9).

Table 6. Results of individual trawl tows for small pelagic fish in Kanalku Lake, 10 Aug. 2002.

Tow	Depth (m)	Time (min)	Species	No. of Fish
1	Surface	15		0
2	9	15	Sockeye age 0	1
3	9	15		0
4	12	15	Sockeye age 0	1
5	12	15	Sockeye age 0	1
			Sculpin	1

Kook Lake

Hydroacoustic and trawl surveys were completed in Kook Lake on August 12. The total hydroacoustic target estimate was 49,465 fish (CV 5%). Five trawl tows were conducted, and a total of 15 sockeye fry and no other species were caught among all tows (Table 7). All the sockeye fry were under 50 mm in length and assumed to be age-0. Therefore, all acoustic targets were assumed to be age-0 sockeye salmon, and the total population estimate of sockeye fry was about 49,000 (CV 5%). The estimated sockeye fry density in the lake was 0.02 fry · m^{-2} (Table 9).

Table 7. Results of individual trawl tows for small pelagic fish in Kook Lake, August 12, 2002.

Tow #	Depth (m)	Time (min)	Species	Number of Fish
5	Surface	25	Sockeye age 0	1
3	9	25	Sockeye age 0	9
4	9	25		0
1	12	25		0
2	12	30	Sockeye age 0	5

Sitkoh Lake

Hydroacoustic and trawl surveys were completed in Sitkoh Lake on August 14. The total hydroacoustic target estimate was 151,065 fish (CV 9%). In Sitkoh Lake, four midwater tows and one surface tow were conducted, with fish caught in each (Table 8). In the total sample of 43 fish, 42 were sockeye fry and one was a sculpin. Although 20 sockeye fry were greater than 50 mm in length, all were age-0 (Figure 7). Species apportionment for the hydroacoustic targets was assumed to be 98 % age-0 sockeye salmon and 2% sculpins, based on these limited samples. The estimated total population of sockeye fry was about 147,500, and the estimated density of sockeye fry in the lake was 0.11 fry · m^{-2} (Table 9).

Table 8. Results of individual trawl tows for small pelagic fish in Sitkoh Lake, August 14, 2002.

Tow	Depth (m)	Time (min)	Species	Number of Fish
5	Surface	20	Sockeye age 0	1
3	8	20	Sockeye age 0	25
4	8	30	Sockeye age 0	7
1	10	15	Sockeye age 0	6
			Sculpin	1
2	12	15	Sockeye age 0	3

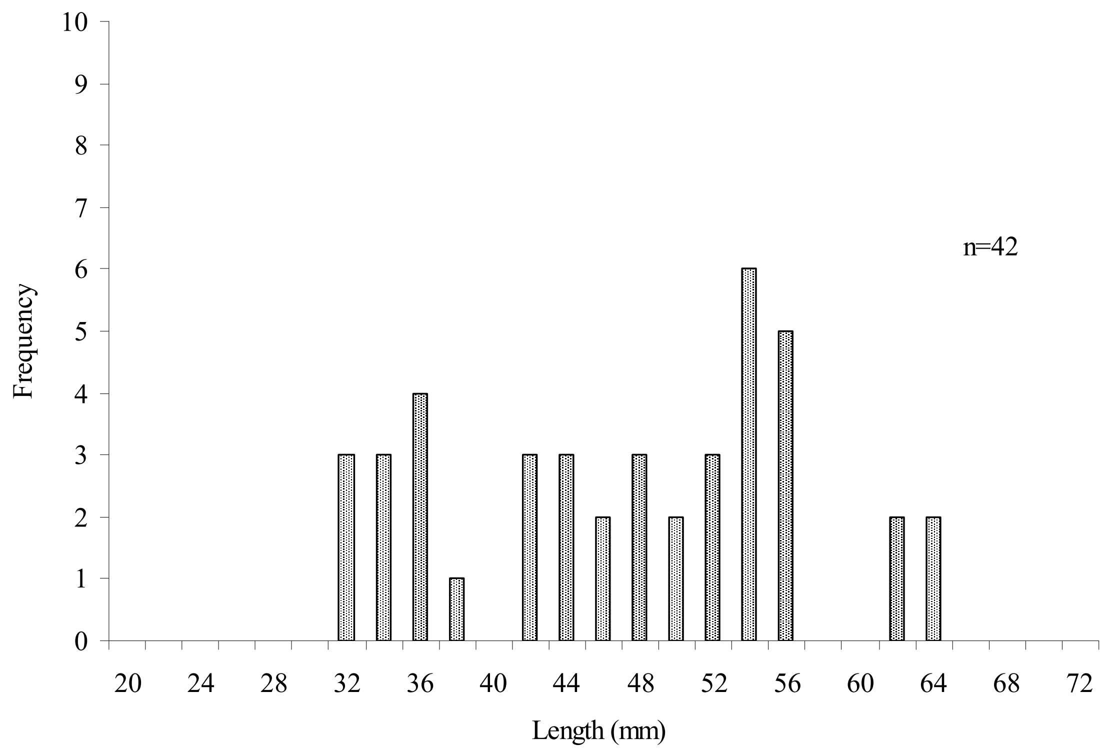

Figure 7. Length frequency distribution of sockeye salmon fry sampled in Sitkoh Lake, 2002. All fish under 50 mm in length were assumed to be age-0 and scale analysis showed those over 50 mm were also age-0.

Table 9. Sample sizes, abundances, and mean lengths and weights by species and, for sockeye fry by age, from trawls in Kanalku, Kook and Sitkoh Lakes, 2002. Sample standard deviations are indicated for mean lengths and weights.

Lake	Species	Age	Sample size	Proportion of total	Mean length (mm) ± stdev	Mean weight (g) ± stdev	Estimated Total by Species, Age
Kanalku	Sockeye	0	3	75%	43± 8.7	1 ± 0.5	21,525
	Sculpin	na	1	25%	25	0.2	7,175
Kook	Sockeye	0	15	100%	42.6± 4.4	0.75 ± 0.23	49,465
Sitkoh	Sockeye	0	42	98%	46.9± 9.4	1.1 ± 0.6	147,552
	Sculpin	na	3	2%	27	0.2	3,513

Adult Escapement Estimates

Mark-Recapture and Visual Survey

Kanalku Lake

Four surveys were conducted at Kanalku Lake between August 16 and September 29, 2002 (Table 10). Although the total sockeye spawner count on the first trip, 16 Aug., was high, the fish were dispersed and not available for sampling on the spawning grounds. Mark and recapture sampling was started on the second trip, September 1. By the fourth trip, and the third mark-recapture event on September 30, the number of spawners had fallen to under 100, so a fourth mark-recapture event was not scheduled.

Table 10. Visual counts of sockeye spawners in Kanalku Lake, listed individually by date and observer (3 - 4 observers). Shoreline areas were surveyed by boat. The study area count was a designated stratum within the total lake shoreline count.

	Sockeye Counts	
Date	Study Area	Entire Lake Shore
8/16	111, 92, 95, 108	781, 706, 748, 705
8/31	586, 766, 596, 476	760, 1145, 758, 642
9/19	587, 524, 523	685, 616, 620
9/30	40, 45, 38, 55	42, 47, 40, 57

The largest samples of sockeye spawners were obtained on the first sampling event, September 1-2 (Table 11), indicating that this was the peak of the spawning period. Sample sizes remained high on the second event two weeks later, but on the third sampling event, very few fish were present on the spawning grounds and samples were small. On the third sampling event, there were no second stage recaptures, which reduced the number of time intervals used in the Jolly-

Seber estimate to one (Table 11). The sockeye escapement estimate within the study area was 1,298 (95% CI 1,211 - 1,398), with a coefficient of variation (CV) of 4%, which met our objective for precision.

Table 11. Sample sizes and numbers of recaptured fish in the Kanalku Lake study area. In the first stage sampling, fish were marked on one day and examined for marks the following day, assuming the population to be closed over this short time period. In the second stage sampling, fish caught on both days of an event were given a unique mark for that event, and were also examined for marks given on previous events. The second stage allowed for an open population estimate.

	First Stage			
Event Dates	**No. Marked (day 1)**	**No. Sampled (day 2)**	**No. Recaps from day 1**	
9/1-2	391	435	248	
9/13-14	339	317	177	
9/27-28	23	19	11	
	Second Stage			
		Recaps from event:		
	No. Marked	**1**	**2**	**3**
9/1-2	578	-	-	-
9/13-14	479	77	-	-
9/27-28	31	0	0	-

<u>Kook Lake</u>

Five visual surveys were conducted at Kook Lake between August 18 and October 14 (Table 12). The inlet stream, Kook Creek, was only surveyed on the first two trips. On the second trip, only 15 sockeye spawners were seen in Kook Creek, in very late stages of spawning, so Kook Creek was not surveyed on subsequent trips. However, the crew observed flood conditions, and a few coho salmon present in the inlet on the third trip, indicating that sockeye spawning there was probably finished.

Table 12. Visual counts of sockeye spawners in Kook Lake, listed individually by date and observer (3 - 4 observers). Shoreline areas were surveyed by boat. The two study areas were designated strata within the total lake shoreline. Counts were made in the inlet stream on foot, and kept separate from the shoreline area counts. Foot surveys were discontinued after September 16, since so few spawners were left in the stream.

	Sockeye Counts			
Date	**Study Area 1**	**Study Area 2**	**Entire Lake Shore**	**Inlet Stream**
8/18	27, 2, 26	27, 27, 24, 27	57, 30, 28, 38	158, 155, 192, 158
9/2	435, 356, 421, 314	124, 100, 96, 96	603, 491, 550, 444	15
9/16	572, 565, 835	147, 240, 193	820, 924, 1152	-
9/29	386, 436, 446	92, 107, 80	560, 631, 607	-
10/14	135, 137, 127	18, 15, 16	197, 196, 184	-

The mark-recapture study area was changed in 2002 from that used in 2001 (Conitz and Cartwright 2002b). Sampling was attempted in the 2001 study area (see Figure 4, study area 1a, 1b) on each trip, and although there were many more spawners present in 2002 than in 2001, a steep drop-off and many submerged logs made it very difficult to capture fish with a beach seine in that study area. However, beach spawners were found at another location that was more accessible to the beach seine, so that area was selected as a new study area in 2002 (see Figure 4, study area 2). Mark-recapture studies were conducted in both study areas (1 and 2). Although at least one marked fish was observed to stray from study area 2 to study area 1, the areas were widely separated and it was assumed that there was little mixing of fish between areas once they were actively spawning. Mark-recapture data were analyzed for the two study areas separately and combined. However, combining the data from the two study areas may violate the mark-recapture assumptions of equal capture probabilities or complete mixing of marked and unmarked fish (Seber 1982). There were very few second stage recaptures in study area 1, so we decided to use only data from study area 2 in the analysis (Table 13). The escapement estimate for the study area was 590 (95% CI 485 - 814) sockeye salmon; the CV of 15% for the study area estimate just met the objective. The study area did not constitute the major spawning area in Kook Lake, and so the proportion of fish accessible for the mark-recapture estimate was low.

Table 13. Sample sizes and numbers of recaptured fish in study area 2 at Kook Lake.

	First Stage			
Event Dates	**No. Marked (day 1)**	**No. Sampled (day 2)**	**No. Recaps from day 1**	
9/2-4	24	21	5	
9/16-18	66	70	31	
9/29-10/1	38	57	18	
10/13-15	40	22	9	
	Second Stage			
		Recaps from event:		
	No. Marked	**1**	**2**	**3**
9/2-4	40	-	-	-
9/16-18	105	16	-	-
9/29-10/1	77	1	19	-
10/13-15	53	0	0	3

Sitkoh Lake

Six visual surveys were conducted at Sitkoh Lake between August 20 and November 5 (Table 14). Only the shoreline areas of the lake were surveyed, as historically, no sockeye spawners have been observed in the inlet streams. The peak number of sockeye salmon observed visually was on September 19.

Table 14. Visual counts of sockeye spawners in Sitkoh Lake, listed individually by date and observer (3 - 4 observers). Shoreline areas were surveyed by boat. The study area count was a designated stratum within the total lake shoreline count.

	Sockeye Counts	
Date	**Study Area**	**Entire Lake Shore**
8/20	159, 140, 141, 135	229, 205, 205, 196
9/4	307, 285, 430	661, 656, 911
9/19	382, 342, 514	784, 709, 959
10/2	395, 383, 421	713, 726, 831
10/17	524, 489, 583	724, 627, 777
11/4	112, 82, 113, 196	116, 88, 121, 204

A total of six mark and recapture events were conducted in Sitkoh Lake, with spawners available for sampling on the first trip starting August 20 and new fish continuing to appear on the spawning grounds through early Nov. (Table 15). The escapement estimate for the study area was 7,254 (95% CI 6,536 - 8,174) sockeye salmon, and the CV was 6%, meeting our objective for precision.

Table 15. Sample sizes and numbers of recaptured fish in Sitkoh Lake.

	First Stage		
Event Dates	**No. Marked (day 1)**	**No. Sampled (day 2)**	**No. Recaps from day 1**
8/20-22	77	121	38
9/4-6	252	213	108
9/19-21	358	280	164
10/2-4	387	322	163
10/17-19	342	393	180
11/4-5	83	78	30

	Second Stage					
		Recaps from event:				
	No. Marked	**1**	**2**	**3**	**4**	**5**
8/20-22	160	-	-	-	-	-
9/4-6	357	32	-	-	-	-
9/19-21	474	1	21	-	-	-
10/2-4	546	0	7	42	-	-
10/17-19	555	0	0	0	23	-
11/4-5	131	0	0	0	0	2

Adult Sockeye Salmon Population Age and Size Distribution

Kanalku Lake

At Kanalku Lake, 526 sockeye salmon were sampled, of which 266 were males and 260 were females. Age could not be determined in 104 of the sampled fish, and sex was not recorded for four fish. The age structure of the sockeye salmon in the sample was very simple, with only the age-1.2, age-1.3, and age-2.2 classes represented. Out of 426 ageable samples, the dominant class for both sexes was age-1.2, at about 80% of the total sample (Table 16). About 16% of the sample was age-1.3.

Table 16. Age composition of adult sockeye salmon sampled in the Kanalku Lake escapement by sex, August 31 - September 29, 2002.

Brood Year	**1998**	**1997**	**1997**	
Age Class	**1.2**	**1.3**	**2.2**	**Total**
Male				
Sample Size	154	50	5	209
Percent	36.5	11.8	1.2	49.5
Std. Error	2.3	1.6	0.5	2.4
Female				
Sample Size	186	18	9	213
Percent	44.1	4.3	2.1	50.5
Std. Error	2.4	1	0.7	2.4
All Fish				
Sample Size	342	70	14	426
Percent	80.3	16.4	3.3	100
Std. Error	1.9	1.8	0.9	

The average mid-eye to fork length of the age-1.2 fish sampled in Kanalku Lake was 477 mm, and the average fork length over all age classes was about 485 mm (Table 17). Age-1.3 fish averaged 530 mm in length. The average fork length of the fish that were not aged fell very close to the overall averages, indicating that their age composition was similar to the aged sample.

Table 17. Mean fork length (mm) of adult sockeye salmon in the Kanalku Lake escapement by sex and age class, August 31 - September 29, 2002.

Brood Year	**1998**	**1997**	**1997**		
Age Class	**1.2**	**1.3**	**2.2**	**Not Aged**	**All Fish**
Male					
Av. Length	481	537	496	491	493
SE (av. length)	1.8	3.1	11.1	4.1	2.0
Sample size	154	48	5	56	263
Female					
Av. Length	474	510	473	478	477
SE (av. length)	1.3	4.0	10.3	3.8	1.4
Sample size	185	18	9	47	259

Table 17. Continued - Mean fork length (mm) of adult sockeye salmon in the Kanalku Lake escapement by sex and age class, August 31 - September 29, 2002.

Brood Year	**1998**	**1997**	**1997**		
Age Class	**1.2**	**1.3**	**2.2**	**Not Aged**	**All Fish**
Not Sexed					
Av. Length	457	555		575	511
SE (av. length)	18.5				32.5
Sample size	2	1		1	4
All Fish					
Av. Length	477	530	481	486	485
SE (av. length)	1.1	2.9	8.1	3.0	1.3
Sample size	341	67	14	104	526

Kook Lake

At Kook Lake, 475 sockeye salmon were sampled, of which 235 were males and 240 were females. Age could not be determined in 75 of the samples. Out of 400 ageable samples, the dominant class for both sexes was age-1.2, at about 80% of the total sample (Table 18). About 16% of the samples were age-1.3; only one or two individuals represented the three other age classes present in the sample.

Table 18. Age composition of adult sockeye salmon sampled in the Kook Lake escapement by sex, September 2 - October 16, 2002.

Brood Year	**1999**	**1998**	**1997**	**1997**	**1996**	
Age Class	**0.2**	**1.2**	**1.3**	**2.2**	**2.3**	**Total**
Male						
Sample Size		139	44			183
Percent		34.8	11			45.8
Std. Error		2.4	1.6			2.5
Female						
Sample Size	1	182	31	1	2	217
Percent	0.3	45.5	7.8	0.3	0.5	54.3
Std. Error	0.2	2.5	1.3	0.2	0.3	2.5
All Fish						
Sample Size	1	322	75	1	2	401
Percent	0.2	80.3	18.7	0.2	0.5	100
Std. Error	0.2	2	1.9	0.2	0.3	

The average mid-eye to fork length of the age-1.2 fish sampled in Kook Lake was 473 mm, and the average fork length over all age classes was about 483 mm (Table 19). Age-1.3 fish averaged 523 mm in length.

Table 19. Mean fork length (mm) of adult sockeye salmon in the Kook Lake escapement by sex and age class, September 2 – October 16, 2002.

Brood Year Age Class	1999 0.2	1998 1.2	1997 1.3	1997 2.2	1996 2.3	Not Aged	All Fish
Male							
Av. Length		482	529			489	492
SE (av. length)		1.8	3.7			4.1	1.9
Sample Size		139	44			52	235
Female							
Av. Length	480	466	514	485	525	472	474
SE (av. length)		1.5	4.0		5.0	3.4	1.7
Sample Size	1	182	31	1	2	23	240
All Fish							
Av. Length	480	473	523	485	525	484	483
SE (av. length)		1.2	2.8		5.0	3.1	1.3
Sample Size	1	321	75	1	2	75	475

Sitkoh Lake

At Sitkoh Lake, 609 sockeye salmon were sampled, of which 331 were males and 278 were females. Age could not be determined for 67 fish. Of the 543 samples that were aged, 61% were age-1.3 and 36% were age-1.2; there were only a few individuals in other age classes, including 6 jacks (Table 20).

Table 20. Age composition of adult sockeye salmon sampled in the Sitkoh Lake escapement by sex, August 20 - October 4, 2002.

Brood Year Age Class	1999 1.1	1998 1.2	1997 1.3	1997 2.2	1996 2.3	Total
Male						
Sample Size	6	104	180	3	3	296
Percent	1.1	19.2	33.2	0.6	0.6	54.6
Std. Error	0.4	1.7	2	0.3	0.3	2.1
Female						
Sample Size		90	151	4	1	246
Percent		16.6	27.9	0.7	0.2	45.4
Std. Error		1.6	1.9	0.4	0.2	2.1
All Fish						
Sample Size	6	195	331	7	4	543
Percent	1.1	35.9	61	1.3	0.7	100
Std. Error	0.4	2	2.1	0.5	0.4	

The overall average mid-eye to fork length was 522 mm, reflecting the higher proportion of age-1.3 fish in Sitkoh Lake samples. Age-1.2 fish averaged 487 mm (Table 21).

Table 21. Mean fork length (mm) of adult sockeye salmon in the Sitkoh Lake escapement by sex and age class, August 20 – October 4, 2002.

Brood Year	**1999**	**1998**	**1997**	**1997**	**1996**		
Age Class	**1.1**	**1.2**	**1.3**	**2.2**	**2.3**	**Not Aged**	**All Fish**
Male							
Av. Length	344	490	555	522	552	509	526
SE (av. length)	9.0	2.2	1.4	7.3	1.7	8.2	2.5
Sample Size	6	104	180	3	3	35	331
Female							
Av. Length		484	539	488	570	519	518
SE (av. length)		2.4	1.7	4.8		5.5	2.0
Sample Size		90	151	4	1	32	278
Not Sexed							
Av. Length		500					500
SE (av. length)							
Sample Size		1					1
All Fish							
Av. Length	344	487	548	502	556	514	522
SE (av. length)	9.0	1.6	1.2	7.9	4.7	5.0	1.7
Sample Size	6	195	331	7	4	67	610

Limnology

Light, Temperature, and Dissolved Oxygen Profiles

The mean euphotic zone depths (EZD) in 2002 were about 12 m at Kanalku Lake and 6 m at Kook and Sitkoh Lakes (Table 22). Minimum depths for the season at all three lakes occurred in fall, coinciding with heavy rainfall and maximum sediment input.

Table 22. Euphotic zone depths in Kanalku, Kook, and Sitkoh Lakes, 2002.

Lake	Sample date	EZD (m)
Kanalku	24-May	12.16
	9-Jul	13.46
	16-Aug	13.79
	28-Sep	10.59
	Seasonal mean	12.50
Kook	24-May	6.16
	9-Jul	7.90
	19-Aug	6.74
	30-Sep	4.83
	Seasonal mean	6.41
Sitkoh	24-May	5.90
	9-Jul	6.99
	21-Aug	5.77
	2-Oct	5.71
	Seasonal mean	6.09

Warming of the epilimnion was already evident in Kanalku Lake by the first sampling date, May 24, but Kook and Sitkoh Lakes were still isothermic due to their greater depth (Figure 8). Thermoclines were beginning to form in all three lakes by July 9, and had deepened to the 10-15 m depth in all the lakes in August, with the greatest amount of structure in Sitkoh Lake. Maximum epilimnetic temperatures were between 15^{o}-$16^{o}C$ in all three lakes in mid-Aug. The minimum temperatures in the hypolimnion were between 4^{o}-$5^{o}C$, depending on depth, in the lakes. Dissolved oxygen (DO) levels were above 90% saturation at all depths in Kook and Sitkoh Lakes in late May, but were below that in Kanalku Lake in July (Table 23). It is possible that measurement error, such as an error in the Winkler titration, caused the low readings at Kanalku Lake in July, but DO should be monitored in Kanalku Lake again in 2003 and future seasons.

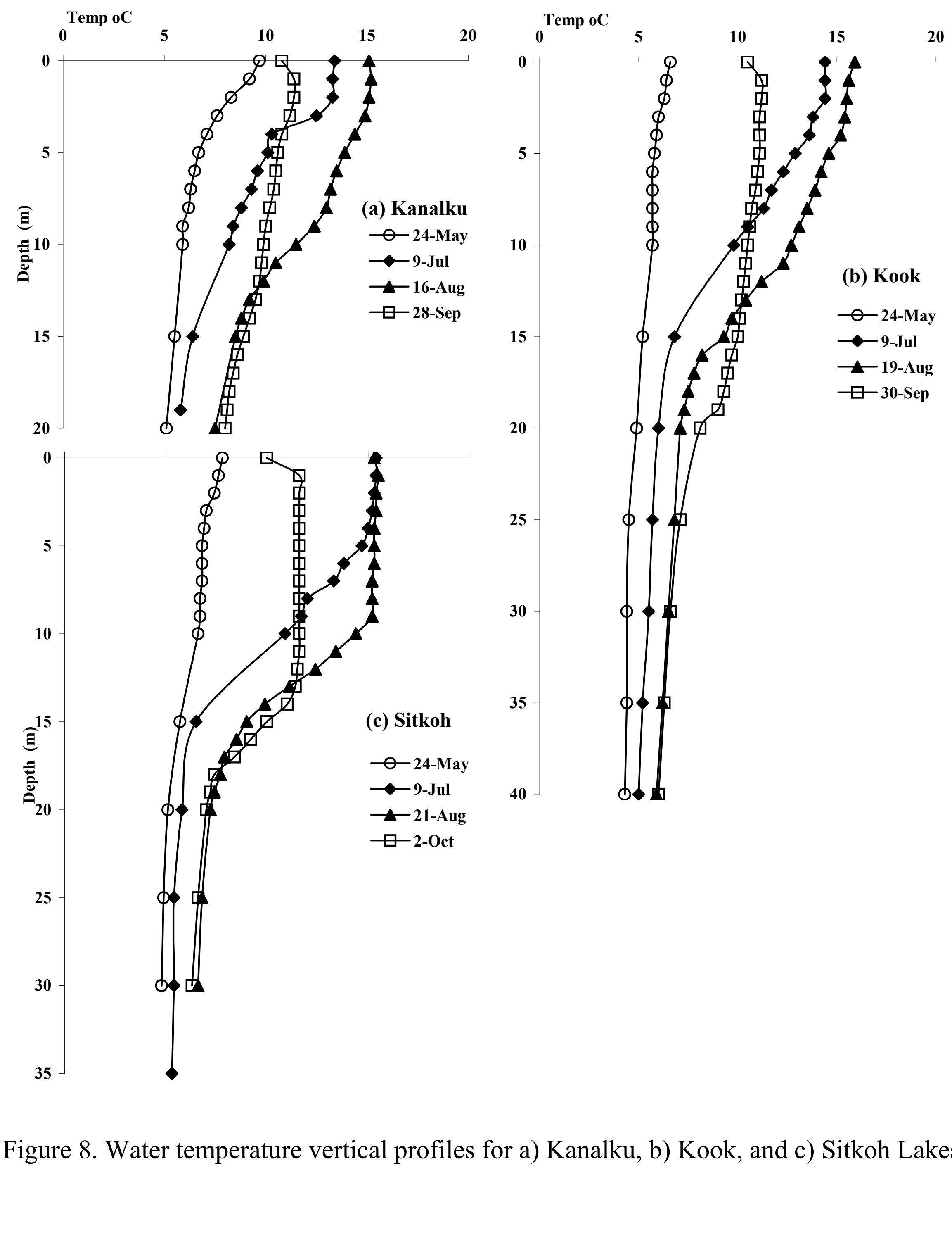

Figure 8. Water temperature vertical profiles for a) Kanalku, b) Kook, and c) Sitkoh Lakes, 2002.

Table 23. Dissolved oxygen (DO) profiles from Kanalku, Kook, and Sitkoh Lakes, expressed as percent O_2 saturation. Measurements were made in Kanalku Lake on July 9, and in Kook and Sitkoh Lakes on May 24, 2002.

	Dissolved O_2 (% Saturation)		
Depth (m)	**Kanalku**	**Kook**	**Sitkoh**
0		103.2	98.5
1	82.1	102.3	97.5
2	81.9	102.7	98.0
3	82.5	101.8	96.6
4	81.7	101.5	96.1
5	82.3	101.4	96.3
6	82.2	100.9	96.9
7	81.9	101.0	96.0
8	81.4	101.2	96.0
9	81.1	101.1	95.9
10	80.5	101.0	95.8
15	76.1	100.0	93.1
20	71.5	99.1	92.0
25		98.2	91.2
30		97.6	90.6
35		97.3	
40		96.8	

Secondary Production

Major taxa of macro-zooplankton identified in water samples from Kanalku, Kook and Sitkoh Lakes were cladocerans *Bosmina* sp., *Daphnia longiremis*, *Holopedium* sp., and copepods *Diaptomus* sp. and *Cyclops* sp. Additional taxa identified in samples from Kanalku Lake were the cladoceran *Sida* sp. and the copepod *Epischura* sp. In Kook and Sitkoh Lakes, zooplankton was identified to species. Besides *Daphnia longiremis*, the cladocerans *Bosmina coregoni* and *Holopedium gibberum* were present in both lakes. Kook Lake also had the copepod species *Diaptomus tyrrelli* and *Cyclops scutifer*, while *Cyclops vernalis* was the single copepod species identified from Sitkoh Lake samples. All three lakes had moderate to high zooplankton abundance, with Sitkoh Lake having the highest.

Kanalku Lake

Zooplankton abundance was moderate at Kanalku Lake, with total seasonal mean biomass of 370 and 470 $mg \cdot m^{-2}$ at stations A and B, respectively (Table 24). The total seasonal mean density was 130,000 and 123,000 zooplankters $\cdot m^{-2}$ at stations A and B, respectively (Table 25). Cladocerans were dominant both in terms of biomass and numbers, and *D. longiremis* represented the highest proportions of both biomass and numbers. Over one-third of the total mean biomass of *D. longiremis* was comprised of ovigorous individuals, with average lengths of 1.2 mm or greater; average lengths of non-ovigorous *D. longiremis* were about 0.75 mm.

Table 24. Estimates of size and biomass of macrozooplankton in Kanalku Lake by station for May – September 2002. Mean lengths are weighted by density (numbers · m^{-2}) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxa were measured separately.

	Average Length (mm)				Weighted Mean Length (mm)	Seasonal Mean Biomass ($mg \cdot m^{-2}$)	% Of Total Biomass
Station A	**24-May**	**9-Jul**	**16-Aug**	**28-Sep**			
Epischura	0.85	1.68	1.68	1.56	1.49	47	10.0%
Diaptomus	0.62	1.22	1.15	1.27	1.11	39	8.2%
Ovig. Diaptomus		1.95			1.95	15	3.2%
Cyclops	0.90	1.09	1.04	0.48	0.96	89	18.9%
Ovig. Cyclops	1.13	1.14	1.13	1.16	1.14	43	9.0%
Bosmina	0.44	0.48	0.54	0.56	0.51	76	16.1%
Ovig. Bosmina	0.51		0.62	0.63	0.63	1	0.2%
Daphnia longiremis	0.66	0.75	0.81	0.75	0.77	101	21.6%
Ovig. D. longiremis	1.02	1.34	1.14	1.09	1.29	40	8.4%
Holopedium	0.63	0.92	0.93		0.91	9	1.9%
Ovig. Holopedium		1.20					0.0%
Sida c.				1.87	1.87	10	2.1%
Ovig. Sida c.				2.30	2.30	1	0.3%
				Total Seasonal Mean Biomass		**471**	
Station B							
Epischura		1.78	1.28	1.57	1.45	28	7.6%
Diaptomus		1.28	1.12		1.28	34	9.4%
Ovig. Diaptomus		1.32			1.32	7	1.8%
Cyclops		1.04	1.14	0.55	0.91	37	10.0%
Ovig. Cyclops		1.12	1.17		1.12	23	6.2%
Bosmina		0.54	0.47	0.58	0.53	88	24.1%
Ovig. Bosmina		0.66	0.64	0.65	0.65	3	0.7%
Daphnia longiremis		0.72	0.74	0.72	0.72	91	24.8%
Ovig. D. longiremis		1.30	1.14	1.09	1.22	43	11.7%
Holopedium		0.84			0.84	14	3.8%
Ovig. Holopedium		1.34					
				Total Seasonal Mean Biomass		**366**	

Table 25. Density (number · m^{-2}) of macrozooplankton by taxa in Kanalku Lake, 2002.

	Density (number · m^{-2})					
Station A	**24-May**	**9-Jul**	**16-Aug**	**28-Sep**	**Seasonal Mean**	**% Of Total Numbers**
Epischura	2,343	2,972	2,445	5,841	3,400	2.6%
Diaptomus	5,094	21,226	408	204	6,733	5.2%
Diaptomus, Ovig.	0	2,123	0	0	531	0.4%
Cyclops	45,543	49,669	4,483	7,947	26,910	20.6%
Cyclops, Ovig.	713	33,962	1,358	0	9,008	6.9%
Bosmina	2,343	71,319	37,086	14,875	31,406	24.0%
Bosmina, Ovig.	0	0	272	815	272	0.2%
Daphnia longiremis	2,140	84,055	59,365	9,917	38,869	29.7%
D. longiremis, Ovig.	204	15,707	2,717	1,087	4,929	3.8%
Holopedium	204	3,396	408	0	1,002	0.8%
Holopedium, Ovig.	0	0	0	0	0	0.0%
Sida c.	0	0	0	747	187	0.1%
Sida c., Ovig.	0	0	0	68	17	0.0%
Copepod nauplii	7,539	0	0	22,279	7,455	5.7%
		Seasonal Mean Density, All Taxa			**130,718**	
Station B						
Epischura		1,274	3,464	1,630	2,123	1.7%
Diaptomus		11,887	102	0	3,996	3.2%
Ovig. Diaptomus		2,123	0	0	708	0.6%
Cyclops		21,226	5,196	10,698	12,373	10.0%
Ovig. Cyclops		14,009	815	0	4,941	4.0%
Bosmina		56,037	23,332	18,339	32,569	26.4%
Ovig. Bosmina		425	102	1,325	617	0.5%
Daphnia longiremis		63,254	36,577	19,664	39,831	32.3%
D. longiremis, Ovig.		10,613	2,241	5,196	6,017	4.9%
Holopedium		5,519	0	0	1,840	1.5%
Ovig. Holopedium		0	0	0	0	0.0%
Copepod nauplii		0	0	54,814	18,271	14.8%
		Seasonal Mean Density, All Taxa			**123,286**	

Kook Lake

Zooplankton biomass and abundance were moderate in Kook Lake, but somewhat lower than in Kanalku Lake. The total seasonal mean biomass was 340 and 270 mg·m^{-2} at stations A and B, respectively (Table 26). The total seasonal mean density was 115,000 and 87,000 zooplankters ·m^{-2} at stations A and B, respectively (Table 27). The smaller cladoceran *Bosmina coregoni* (average length 0.5 mm) was dominant in both biomass and numbers, while the copepod *Cyclops scutifer* was the second most abundant taxon. The larger (average length 0.8 mm) *D. longiremis* was also present in moderate proportions, about 12-16% of both biomass and overall numbers.

Table 26. Estimates of size and biomass of macrozooplankton in Kook Lake by station for May – September 2002. Mean lengths are weighted by density (numbers · m-2) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxa were measured separately.

	Average Length (mm)						
Station A	**24-May**	**9-Jul**	**18-Aug**	**30-Sep**	**Weighted Mean Length (mm)**	**Seasonal Mean Biomass ($mg \cdot m^{-2}$)**	**% Of Total Biomass**
Diaptomus tyrrelli		0.99	1.39	1.42	1.16	8	2.4%
Ovig. D. tyrrelli			1.40	1.43	1.42	2	0.6%
Cyclops scutifer	0.61	0.96	0.98	1.01	0.78	94	27.4%
Ovig. C. scutifer	1.27	1.24	1.33	1.28	1.28	8	2.2%
Bosmina coregoni	0.46	0.50	0.55	0.56	0.54	117	33.9%
Daphnia longiremis	0.71	0.81	0.83	0.79	0.80	55	15.9%
Ovig. D. longiremis	1.16	1.14	1.10	1.05	1.11	5	1.4%
Holopedium gibberum	0.38	1.15	0.79	1.17	1.02	55	16.1%
Ovig. H. gibberum			1.04	1.10	1.10	0	0.1%
				Total Seasonal Mean Biomass		**345**	
Station B							
Diaptomus tyrrelli		0.93	1.36	1.36	1.19	12	4.4%
Ovig. D. tyrrelli			1.47	1.41	1.44	1	0.4%
Cyclops scutifer	0.69	0.99	0.98	0.91	0.86	70	25.4%
Ovig. C. scutifer	1.25	1.25	1.27	1.30	1.26	5	1.8%
Bosmina coregoni	0.43	0.49	0.52	0.51	0.51	91	32.8%
Daphnia longiremis	0.72	0.77	0.86	0.77	0.79	35	12.6%
Ovig. D. longiremis	1.11	1.18	1.08	1.04	1.09	6	2.1%
Holopedium gibberum	0.40	1.03	0.97	1.22	0.92	56	20.2%
Ovig. H. gibberum		1.30	1.10	1.23	1.23	1	0.3%
				Total Seasonal Mean Biomass		**276**	

Table 27. Density (number · m^{-2}) of macrozooplankton by taxa in Kook Lake, 2002.

	Density (number · m^{-2})					
Station A	**24-May**	**9-Jul**	**18-Aug**	**30-Sep**	**Seasonal Mean**	**% Of Total Numbers**
Diaptomus tyrrelli	0	3,057	408	1,630	1,274	1.1%
Ovig. D. tyrrelli	0	0	272	408	170	0.1%
Cyclops scutifer	94,498	48,395	18,611	16,981	44,621	38.7%
Ovig. C. scutifer	1,104	2,292	1,630	0	1,257	1.1%
Bosmina coregoni	2,123	33,622	39,124	91,289	41,539	36.0%
Ovig. B. coregoni	0	0	0	0	0	0.0%
Daphnia longiremis	5,773	28,273	20,241	22,551	19,210	16.6%
Ovig. D. longiremis	764	764	1,087	679	824	0.7%
Holopedium gibberum	849	11,971	5,026	815	4,665	4.0%
Ovig. H. gibberum	0	0	0	136	34	0.0%
Copepod nauplii	7,302	0	0	0	1,825	1.6%
		Seasonal Mean Density, All Taxa			**115,419**	

Table 27. Continued - Density (number · m^{-2}) of macrozooplankton by taxon in Kook Lake, 2002.

Station B	24-May	9-Jul	18-Aug	30-Sep	Seasonal Mean	% Of Total Numbers
	Density (number · m^{-2})					
Diaptomus tyrrelli	0	2,853	3,566	594	1,753	2.0%
Ovig. D. tyrrelli	0	0	170	170	85	0.1%
Cyclops scutifer	43,335	37,086	14,773	12,736	26,983	31.0%
Ovig. C. scutifer	408	1,358	1,528	85	845	1.0%
Bosmina coregoni	1,630	32,875	64,527	48,056	36,772	42.2%
Ovig. B. coregoni	0	0	0	85	21	0.0%
Daphnia longiremis	3,600	15,622	13,075	18,169	12,617	14.5%
Ovig. D. longiremis	1,223	543	1,019	1,358	1,036	1.2%
Holopedium gibberum	2,513	1,766	19,019	679	5,994	6.9%
Ovig. H. gibberum	0	0	0	170	42	0.0%
Copepod nauplii	3,668	0	0	0	917	1.1%
			Seasonal Mean Density, All Taxa		**87,065**	

Sitkoh Lake

Zooplankton abundance was high at Sitkoh Lake, with total seasonal mean biomass of 480 and 660 mg·m^{-2} at stations A and B, respectively (Table 28). The total seasonal mean density was 262,000 and 329,000 zooplankters ·m^{-2} at stations A and B, respectively (Table 29). The copepod *Cyclops vernalis* was dominant in both biomass and numbers, with the exception that *Daphnia longiremis* constituted the highest proportion of the seasonal mean biomass at station B. Although *C. vernalis* was as abundant numerically or more so than the three cladoceran taxa combined, the cladocerans as a group outweighed the sole copepod representative in terms of biomass.

Table 28. Estimates of size and biomass of macrozooplankton in Sitkoh Lake by station for May – October 2002. Mean lengths are weighted by density (numbers · m-2) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxa were measured separately.

Station A	24-May	9-Jul	21-Aug	2-Oct	Weighted Mean Length (mm)	Weighted Biomass (mg·m^{-2})	% Of Total Biomass
	Average Length (mm)						
Cyclops vernalis	0.52	0.74	0.51	0.57	0.57	153	31.9%
Ovig. C. vernalis	0.88	0.88	0.89	0.89	0.89	3	0.7%
Bosmina coregoni	0.44	0.44	0.47	0.45	0.45	126	26.4%
Ovig. B. coregoni	0.58				0.58	0	0.1%
Daphnia longiremis	0.68	0.83	0.82	0.76	0.81	127	26.6%
Ovig. D. longiremis	0.95	1.07	1.01	0.86	0.99	14	3.0%
Holopedium gibberum	0.38	1.28	0.80	0.94	0.98	54	11.3%
					Total Seasonal Mean Biomass	**479**	

Table 28. Continued - Estimates of size and biomass of macrozooplankton in Sitkoh Lake by station for May – October 2002. Mean lengths are weighted by density (numbers · m-2) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxa were measured separately.

	Average Length (mm)						
Station B	**24-May**	**9-Jul**	**21-Aug**	**2-Oct**	**Weighted Mean Length (mm)**	**Weighted Biomass (mg·m^{-2})**	**% Of Total Biomass**
Cyclops vernalis	0.55	0.64	0.55	0.59	0.58	178	27.0%
Ovig. C. vernalis	0.88	0.87	0.88		0.88	4	0.5%
Bosmina coregoni	0.39	0.45	0.45	0.49	0.46	146	22.1%
Ovig. B. coregoni	0.56		0.62		0.59	1	0.1%
Daphnia longiremis	0.68	0.75	0.80	0.80	0.76	222	33.7%
Ovig. D. longiremis	0.97	1.04	0.99		0.99	10	1.5%
Holopedium gibberum	0.35	1.26	0.88	0.80	1.07	99	15.0%
					Total Seasonal Mean Biomass	**659**	

Table 29. Density (number · m^{-2}) of macrozooplankton by taxa in Sitkoh Lake, 2002.

Station A	**24-May**	**9-Jul**	**21-Aug**	**2-Oct**	**Seasonal Mean**	**% Of Total Numbers**
Cyclops vernalis	112,787	96,791	216,760	146,714	143,263	54.7%
Ovig. C. vernalis	1,019	849	2,292	509	1,167	0.4%
Bosmina coregoni	5,604	123,960	80,489	52,725	65,695	25.1%
Ovig. B. coregoni	509	0	0	0	127	0.0%
Daphnia longiremis	16,505	116,319	32,603	9,424	43,713	16.7%
Ovig. D. longiremis	4,789	3,396	3,821	764	3,192	1.2%
Holopedium gibberum	4,483	11,462	3,566	255	4,941	1.9%
		Seasonal Mean Density, All Taxa			**262,099**	
Station B						
Cyclops vernalis	76,719	155,374	214,637	178,638	156,342	47.5%
Ovig. C. vernalis	917	1,019	3,396	0	1,333	0.4%
Bosmina coregoni	2,955	132,450	80,149	79,810	73,841	22.4%
Ovig. B. coregoni	408	0	340	0	187	0.1%
Daphnia longiremis	12,532	267,448	53,320	18,339	87,910	26.7%
Ovig. D. longiremis	2,343	1,528	5,094	0	2,241	0.7%
Holopedium gibberum	4,890	21,905	1,698	679	7,293	2.2%
		Seasonal Mean Density, All Taxa			**329,148**	

DISCUSSION

This was the second year of study at all three lakes. With the exception of being unable to estimate precision levels for some of the fry estimates, we were able to meet all of our objectives for each lake. The most important results were reliable mark-recapture estimates of sockeye escapement in Kanalku and Sitkoh Lakes. At Kook Lake, mark-recapture sampling was difficult because of lake topography; only a small portion of the spawning population was accessible. Nevertheless, sample sizes were better than in 2001 since the overall number of spawners had increased, and we were able to obtain an estimate for Kook Lake that met our objective for precision.

The estimated escapement of about 1,300 sockeye salmon within the Kanalku Lake study area was an increase of about five times the escapement observed in 2001. Visual survey data indicate that the study area contained about 79% of the total spawning population in the lake (see Table 10, average ratio of sockeye counts within the study area to sockeye counts for total lake perimeter, weighted by estimated escapement in the study area per sampling occasion, Table 11). Thus the total escapement in Kanalku Lake was roughly 1,630 fish.

The Fish and Game Advisory Council in Angoon, in cooperation with ADF&G Commercial Fisheries and USFS management staff, promoted a voluntary moratorium on subsistence fishing in Kanalku Bay during the 2002 season. This action appears to have been successful; the ACA Council and others in Angoon reported that very little fishing occurred in Kanalku Bay in the 2002 season (M. Kookesh ADF&G, personal communication 2003). The increase in escapement can probably be at least partially attributed to this voluntary closure. Only one subsistence permit, harvesting 14 sockeye salmon, was reported in the ADF&G Commercial Fisheries database for 2002 in Kanalku Bay. The commercial seine fishery in nearby areas of Chatham Strait typically starts at the end of June and after most Kanalku sockeye salmon have already entered the Bay, minimizing the number of these sockeye salmon harvested prior to the subsistence fishery. Thus it is reasonable to assume there was very little harvest of Kanalku sockeye salmon in 2002, and the escapement of around 1,600 fish represented most of the total sockeye returns to this system. The average annual sockeye harvest from Kanalku in the preceding decade was over 1,200 and the maximum was over 1,600 according to voluntary reporting on permits (Table 2). If the sockeye returns in 2002 were typical, terminal harvests at this recent rate could take from 75% to nearly 100% of all sockeye salmon returning to this system. Although the 2002 escapement may represent a first step towards recovery of Kanalku sockeye salmon stocks, further progress will depend on ensuring adequate escapement each year. It is likely that terminal area fishing will need to be limited to some extent into the future, and it is essential to continue the stock assessment program.

We also saw a great improvement in the 2002 sockeye escapement into Kook Lake over that in 2001. Mark-recapture sampling continued to present difficulties in this lake; sample sizes were small, and some of the mark-recapture assumptions may not have been met due to the difficulties in capturing fish. We were only able to sample a small proportion of the total escapement in Kook Lake; study area 2 contained an estimated 16% of total escapement, as indicated by visual surveys (Tables 12 and 13). Expanding the study area estimate of 590 fish by this proportion yields a rough total escapement estimate of 3,600 sockeye spawners. Although we are not reporting a formal variance estimate for the whole-lake expansion, it is probably large, and, more importantly, fish in study area 2 did not represent the major spawning aggregation in the system in 2002. However, the visual survey counts and the limited mark-recapture estimate within study area 2 clearly show that the 2002 escapement was several times higher than in 2001. It is also significant to note that sockeye spawners were present in the inlet stream in 2002, the first time this has been observed for several years (A. McGregor ADF&G, personal communication 2002). The increased escapement may have resulted from efforts to clear large woody debris from the outlet stream in 2001 and 2002. It is difficult or impossible to quantify commercial harvest of Kook Lake sockeye salmon, but ADF&G managers have taken the Kook Lake stock into consideration when setting harvest areas and seasons (A. McGregor ADF&G, personal communication 2003). The 2002 terminal area subsistence harvest, according to the ADF&G Commercial Fisheries database, was 645 sockeye salmon, with 38 permits reporting; Angoon residents reported moderate fishing effort at Basket Bay in 2002 (M. Kookesh ADF&G, personal communication 2002).

The sockeye salmon escapement in Sitkoh Lake appeared to remain healthy; the 2002 escapement estimate was of similar magnitude to estimates during the past six years (Cook 1998; Crabtree 2000, 2001; Conitz and Cartwright 2002; Table 30). The methods used for estimating escapement have remained mostly the same from 1999-2002, so comparisons between these years are the most reliable. The whole-lake escapement estimates are informal and do not have associated precision or confidence interval estimates. Prior to 2001, the whole-lake estimate was obtained by expanding the study area estimate by the average proportion of all sockeye spawners observed inside the study area, according to visual surveys. Starting in 2001, the proportion of all sockeye spawners inside the study area, weighted by the study area escapement estimate per sampling occasion, was used to expand the study area escapement estimate to a whole-lake estimate. Subsistence fishing in Sitkoh Bay has been moderate in recent years. The harvest reported for 2002 was 139 sockeye salmon on five permits. Some Angoon residents have said it is difficult to catch fish there without a larger net and boat (M. Kookesh ADF&G, personal communication 2002).

Table 30. Sitkoh Lake sockeye escapement estimates, 1996-2002 (Cook 1998; Crabtree 2000, 2001; Conitz and Cartwright 2002).

		Estimated Sockeye	
Year	**Type of Estimate**	**Study Area**	**Whole Lake**
1996	weir with mark-recap	na	16,300
1997	mark-recap	4,488	5,984
1998	mark-recap (incomplete)	na	6,649
1999	mark-recap	8,318	10,499
2000	mark-recap	12,362	17,040
2001	mark-recap	8,787 (7,914 – 10,993)*	14,134
2002	mark-recap	7,254 (6,536 – 8,174)*	11,915

*95% confidence interval

Sockeye fry sampling was completed in all three lakes in 2002. Because of the highly clumped distribution of fry in the lakes, we were unable to make formal estimates of species apportionment. However, the total hydroacoustic target estimates met our objective for precision in Sitkoh and Kook Lakes, and because only sockeye fry were present in the Kook Lake tow net samples, the total target estimate can be assumed to be a good estimate of sockeye fry. The CV for the total hydroacoustic target estimate in Kanalku Lake (17%) did not meet our precision objective of 10%, probably because of the very low number of acoustic targets. The estimates for 2002 are not directly comparable with the 2001 estimates, because we reviewed and changed the sampling design in 2002, to use replicate transects within each lake section instead of a repeated measure on the same transect. Nevertheless, sockeye fry densities in all three lakes retained approximately the same relative positions compared with other sockeye-producing lakes sampled in 2001 and 2002 (Table 31; Conitz and Cartwright 2002 a, b). Sockeye fry density in Kanalku Lake was among the lowest of all surveyed lakes in 2001. Although it ranked somewhat higher in 2002, sockeye fry density in Kanalku Lake remained very low and was among the lowest one-third of all surveyed lakes for fry density. Fry density in Kook Lake was likewise very low in both years, also ranking among the lowest one third of surveyed lakes. Fry density in Sitkoh Lake was just above the median. Fry density in each of the three lakes was well below a typical carrying capacity found in most oligotrophic Alaskan lakes of about 20 sockeye fry per 100 m^2 (A. Mazumder University of Victoria, personal communication 2002).

Very small sample sizes obtained with the trawl net, combined with the highly clumped distribution of fry, remained a problem for estimating species apportionments in all three lakes. In Kanalku Lake, only four fish were caught in five trawl samples. No age-1 sockeye fry were caught in any of the trawl samples, a result of the very small sample sizes along with an apparent gear selectivity bias against older fry. However, it is interesting to note that among the adult samples, there were also very few fish with two freshwater years. Age 2. - Adults represented only 3%, 1%, and 2% of samples of at least 400 fish at Kanalku, Kook, and Sitkoh Lakes, respectively. Because of the difficulty of obtaining adequate fry samples by trawling, it will be necessary to sample smolt in these systems to better understand the age distribution of juveniles.

Table 31. Sockeye fry densities in Southeast Alaska lakes producing important subsistence runs, 2002. Total population estimates of small pelagic fish were based on hydroacoustic surveys of each lake, and sockeye populations were estimated from the proportions of sockeye fry in tow net samples. Fry density estimates are the total sockeye population divided by the estimated surface area for each lake.

Lake	Date Sampled	Fry·100 m^{-2}
Hetta	July 18	44
Gut	August 23	25
Kutlaku	August 9	25
Klag	August 25	24
Luck	July 22	23
Chilkoot	October 9	20
Hoktaheen	October 13	18
Salmon (Sitka)	August 22	12
Sitkoh	August 13	11
Salmon Bay	September 22	4
Klawock	July 17	4
Chilkat	October 10	3
Kanalku	August 10	3
Klawock II	October 2	3
Kook	August 11	2
Virginia	September 20	2
Falls	August 24	2
Mahoney	August 1	0

Zooplankton sampling showed all three lakes had healthy prey populations for sockeye fry in 2002. The total seasonal mean zooplankton biomass was between 300-600 mg·m^{-2}, above the median of 15 Southeast Alaska sockeye rearing lakes sampled in 2002 (Table 32). These zooplankton biomass levels are well within the range of 100-1,000 mg·m^{-2} over which fry growth appears to show a positive response to prey availability (Edmundson and Mazumder 2001). An even more important measure of prey availability in sockeye rearing lakes may be abundance and biomass of the cladoceran *Daphnia* sp., which is preferred by sockeye fry due to its larger body size and slower movement (A. Mazumder University of Victoria, personal communication 2002). Sitkoh, Kanalku, and Kook Lake ranked 2nd, 3rd, and 4th, respectively, in *Daphnia* biomass among the 15 sockeye rearing lakes associated with this study; *Daphnia* represented 33%, 33%, and 16% of total seasonal mean biomass in Sitkoh, Kanalku, and Kook Lake, respectively (Table 32). The average body length of *Daphnia* individuals in samples from each lake was about 0.8 mm, considered a medium size.

Table 32. Comparison of zooplankton biomass in 2002 between 15 sockeye rearing lakes in Southeast Alaska that produce important subsistence runs. Biomass was estimated from body length measurements and numbers of individuals in a sample expanded to number per m^2 of lake surface area; seasonal mean biomass was the mean of four samples taken between May and October 2002, at two sampling stations per lake.

Lake	**Seasonal Mean Biomass, All Species ($mg \cdot m^{-2}$)**	***Daphnia* as % of Total Biomass**
Hoktaheen	618	3
Sitkoh	569	33
Neva	476	75
Tumakof	454	0
Kanalku	419	33
Luck	312	6
Kook	311	16
Klag	222	2
Salmon Bay	195	8
Kutlaku	130	27
Thoms	119	6
Hetta	47	10
Falls	29	2
Gut Bay	21	6
Pavlof	1	5

At this early stage of study, it appears sockeye fry populations in Kanalku and Kook Lakes have been limited by low escapements rather than by food availability. Sitkoh Lake had the highest escapement and the highest sockeye fry density of the three lakes in this study. On the other hand, Sitkoh Lake also supports abundant populations of Dolly Varden char, steelhead and cutthroat trout, which potentially limit the number of sockeye fry produced (Beauchamp, 1994; Beauchamp et al. 1995; Cartwright et al. 1998). Interestingly, Sitkoh Lake also had highest biomass and abundance of zooplankton, and of *Daphnia* specifically, among the three lakes in this study. Although the physical characteristics of the three lakes appear to be similar, there may be some combination of factors, which favors zooplankton production in Sitkoh Lake or gives sockeye fry an advantage in growth. Zooplankton production and other factors influencing sockeye fry population dynamics need to be examined over a range of spawning escapements for a number of years in order to better understand these relationships.

This report covers the second year of study in Kanalku, Kook, and Sitkoh Lakes. While we can compare some of the results to those from the first year of study and previous years' data, where it exists, all results must be considered preliminary until several more years' worth of data are collected. Since the average sockeye salmon generation time is five years, it will be several more years until the consequences of low escapements into Kanalku and Kook Lakes, for example, and any subsequent recoveries, can be observed. Federal funding cuts have already forced us to reduce the scope of sampling for the 2003 season. Since these sockeye salmon runs are all important traditional subsistence resources for Angoon and other rural Southeast Alaska residents, pressure to harvest these resources will undoubtedly continue, especially at Kanalku. Consistent annual monitoring of these sockeye salmon stocks provides the information necessary to achieve a balance between sustainable harvests and adequate escapements.

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